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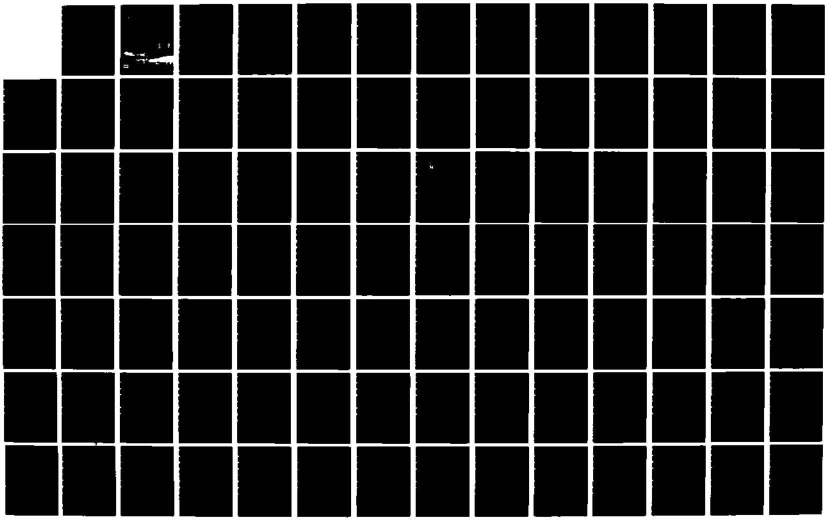

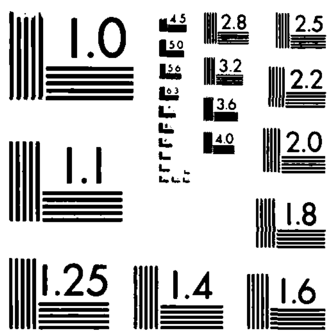
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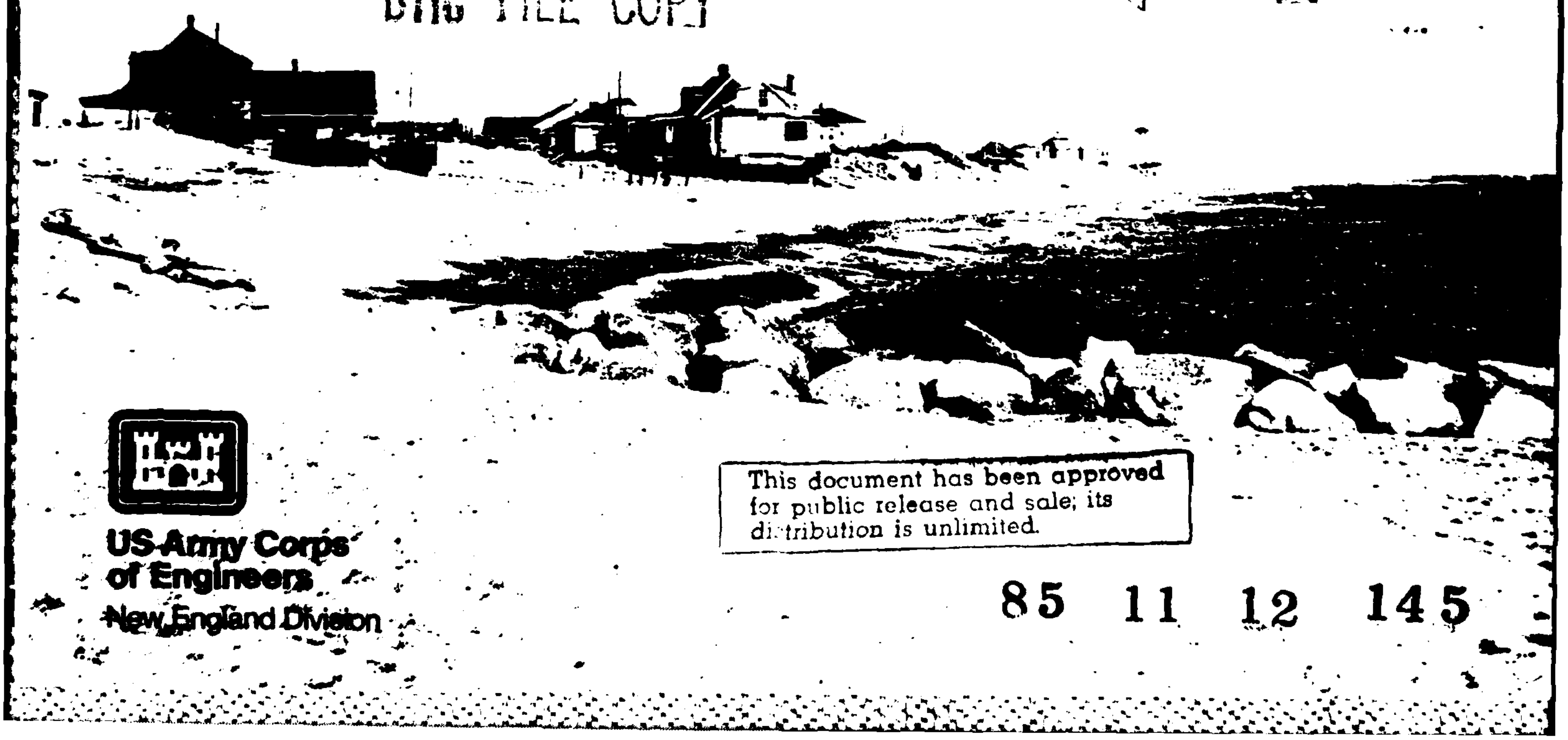
AD-A161 134

New England Regional Coastal Engineering Conference

Fall of 1984 Proceedings



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Shore Erosion

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

On October 30, 31, and November 1, 1984, the Corps sponsored the first New England Regional Coastal Engineering Conference, at the Samoset Resort, Rockport Maine. The agenda included discussion on; Bay of Fundy, Rising Sea Level, Tidal inlets, Impacts on the New England Shoreline due to natural and man-induced Sea Level change. The conference included speakers from the region as well as participants from other Federal, State and National organziations.

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FIRST REGIONAL COASTAL
ENGINEERING CONFERENCE

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FIRST REGIONAL COASTAL ENGINEERING CONFERENCE

October 30 - November 1, 1984
Samoset Resort, Rockport, Maine

A G E N D A

October 30, 1984

0900	Registration	
1300	Poster Session (Schooner Room)	

All speakers will provide at this time a copy of their talk or a detailed summary of the subject to be discussed at the Conference. This session is designed for anyone interested in displaying their ideas or sharing their experiences or problems with others. Speakers are especially encouraged to display information relating to their presentations.

Presentations
(Camden Room)

1530	Bay of Fundy; Tidal Power Developed Impacts from Tides in the Bay of Fundy and Gulf of Maine	Dr. David Greenberg Bedford Institute of Oceanography, Dartmouth, Nova Scotia
1600	Potential Environmental Impacts to the Coastal Zone due to the Bay of Fundy Tidal Power Project	Dr. Peter Larsen Bigelow Labs West Booth Bay, Harbor, Maine
1630	Adjourn	
1800	Dinner	

October 31, 1984
(Camden Room)

0800	Welcome	Lt., Colonel, Edward D. Hammond, Deputy Division Engineer, NED
	Purpose of Conference	Mr. John Smith, Chief, Coastal Development Branch, NED
	Conference Procedures	Mr. Thomas Bruha, Chief, Shore Protection Section, NED

Bay of Fundy

Moderator - Ms. Catherine LeBlanc
Shore Protection Section, NED

0830	Impacts on the Maine Shoreline	Dr. Kenneth Fink Professor, University of Maine
0850	Hydrodynamic Modeling of the Bay of Fundy	Dr. James Houston Chief, Research Division, WESCR
0910	Impacts from the State of Maine Perspective	Mr. David Keeley Maine State Planning Office
0930	Break	
0945	Discussion	

Coastal Inlets

Moderator - Mr. James Doucakis
Shore Protection Section, NED

1030	Tidal Inlets Along the New England Coast	Dr. Duncan Fitzgerald Professor, Boston University
1050	Characteristics and Stability of Tidal Inlets	Mr. Curt Mason, Chief, Field Research Facility, Duck, North Carolina
1110	Navigation Improvement Model Study of Portsmouth Harbor, New Hampshire	Dr. Larry L. Daggett Hydraulic Engineer WESHP-M
1130	Discussion	
1200	Lunch	

Rising Sea Level

Moderator - Dr. Franklin Fessenden
Shore Protection Section, NED
Professor, Bentley College

1330	Sea Level Rise Over the Past Century	Ms. Barbara Braatz Woods Hole Oceanographic Institute
1350	Influence of Sea Level Rise on Inlet Dominated Barrier Island Systems	Dr. Suzette May Research Division, WESCR-P
1410	Impact of Local Sea Level Rise in Maine.	Dr. Joseph Kelley Director, Marine Geology, Maine
1430	Break	
1445	Discussion	
1545	Concurrent sessions in Ebb-Tide Room & Camden Room	

Session A
Planning Concept for Marinas and Maintenance Dredging
(Ebb-Tide Room)

Moderator - Mr. John Smith
Chief, Coastal Development Branch, NED

1545	Planning and Design Alternatives (General Concept)	Mr. Neil Ross, Rhode Island Advisory Service, University of Rhode Island
1605	Marina Case Studies	Mr. Steven Onysko, PE Consulting Engineer Rhode Island
1625	Advanced Maintenance Dredging to Reduce Frequency and Cost	Mr. Michael Trawle Hydraulic Laboratory WESHE-R
1645	Discussion	

Session B
Coastal Processes
(Camden Room)

Moderator - Ms. Jennifer Dick
Shore Protection Section, NED

1545	Nearshore Wave Transformation Along the New England Coast	Dr. Edward Thompson Chief, Coastal Oceanographic Branch, WESCR-O
1605	Regional Coastal Processes Studies	Mr. Thomas Richardson Chief, Coastal Strategy & Evaluation Branch, WESCD-S
1625	Frequency of Wave Overtopping Volumes at Roughans Point	Mr. Lee Butler Chief, Coastal Processes Branch, WESCR-P
1645	Discussion	
1800	Dinner	

Evening Session
(Camden Room)

1930 Sign up at Registration Desk on October 30

Unfortunately, there is never enough time for everyone that has expressed a desire to speak or present his/her ideas during the regular day sessions. This evening session is designed to allow you the opportunity to make a presentation, discuss a problem, or to just discuss different topics with your colleagues. Bring your slides; projectors and trays will be provided.

1930	A Numerical Modeling Characterization of the Annual Three Dimensional Circulation in the Georges Bank - Gulf of Maine Region	Mr. Malcolm Spaulding Applied Science Associates, Inc., Rhode Island
1950	Remote Sensing Techniques to Shore and Beach Erosion, Shoreline Erosion (reservoirs)	Mr. Lawrence Gatto CRREL

\- - - Other Talk - - -

November 1, 1984

Panel Discussion
(Camden Room)

This session is designed to discuss the earlier topics and to adopt a "Where do we go from here?" approach. Discussion should include:

a. Identification of the issue.

b. Summary of major problems and concerns.

c. The efforts each participant sees as the major contribution towards the solutions to the problem.

d. The kinds of support each participant could provide or might recieve from other interested agencies and groups.

e. How cooperation between concerned parties can best be achieved.

		Moderators
0800	Bay of Fundy Dr. James Houston Mr. David Keeley Dr. Peter Larsen Dr. David Greenberg	Dr. Kenneth Fink Professor, University of Maine
0900	Presentations, Comments and Suggestions from the Audience	Mr. Nicholas Avtges Deputy Chief, Planning Division, NED
0945	Break	
1000	Rising Sea Level Ms. Barbara Braatz Dr. Joseph Kelley Dr. Daniel Belknap	Dr. Suzette May Research Division, WESCR
1045	Presentations, Comments and Suggestions from the Audience	Mr. Nicholas Avtges Deputy Chief, Planning Division
1100	Discussion of Future Meeting and Other Coastal Business	
1115	Adjourn	

AGENDA

EVENING SESSION

(Camden Room)

TIME	SPEAKER	SUBJECT
7:30	Mr. Malcolm Spaulding Applied Science Associates, Inc., RI	A Numerical Modeling Characterization of the Annual Three Dimensional Circulation in the Georges Bank - Gulfof Maine Region
7:50	Mr. Lawrence Gatto CRREL	Remote Sensing Techniques to Shore and Beach Erosion, Shoreline Erosion (reservoirs)
8:10	Mr. Roy Socolow USGS	Tide Gaging by Pressure Sensing Manometers
8:30	Mr. David Sanger and Mr. Douglas Kellogg, UMO	Impacts of Erosion on Archaelogical Sites
8:50	Ms. Judy Spiller and Mr. Charles Vorosmarty UNH	EcoSystem-Level Research to Address the Impacts of Altered Tidal Hydrology on Coastal Nutrient Cycling
9:10	Mr. Andrews Tolman Maine Geological Survey	Ground Water Impacts of Rising Sea Level and Development
9:30	Mr. Curt Mason CERC	Research at CERC's Field Research Facility Duck N.C.

Speakers, Please try to limit your presentations to 20 Minutes.

TUESDAY OCTOBER 30, 1984

1:00 p.m.

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P R O C E E D I N G S

MR. BRUHA: Good afternoon. I know there are more people coming. I think it's important that we start either a little early or on time because sometimes the speakers have a tendancy to not run over exactly but -- I won't say anything, David.

By the way in case anyone is interested, my name is Thomas Bruha. I am probably responsible for this. The rest of the people up at the front table are also responsible, so you can blame them as well as me.

I welcome you to your coastal conference, and I say "your" because I'm expecting an awful lot of audience input. And I think it's important that you let us know or let someone here know exactly what you'd like to have discussed during the discussion periods. The speakers will be discussing various topics throughout the day, today and tomorrow, and it's important that you come forth with your ideas and your thoughts and your questions.

It's important also that this little handout that we gave you; that you read it very carefully. There are a lot of neat things in there that pertain to not only the conference but also to mealtimes, and one very important item is that you must, and I repeat you must wear jackets to dinner meals only, and you must have reservations. If you don't, you're going to have a little trouble getting in. You may want to borrow someone's jacket if you didn't bring one. Unfortunately, I only have one so I can't help you there.

After this session is completed, I would like to have, if I may, all the speakers and all the moderators stay around for about 15 minutes, because I have some important items to discuss with them about the session tomorrow, and also regarding how the conference is going to be conducted after today.

This session now will be conducted similar to the rest of the sessions. Let me go over briefly what we will do. We're fortunate today to have two very distinguished speakers, which means the rest of you who are here are also distinguished, but we really are very fortunate to have these two gentleman today to begin the program because they are really going to set the tone for the program, for all the coming sessions.

Our first speaker will be Dr. Greenberg who will discuss the Bay of Fundy tidal power developed impacts from tides in the Bay of Fundy and the Gulf of Maine. Our second speaker is Dr. Larsen who will talk about the potential environmental impacts to the coastal zone due to the Bay of Fundy tidal power project.

Now, what I'd like to do is because these topics are very related to each other, we will let both of these gentleman give their talks and we will save any questions or any discussion period for after they are both finished. That way because they are related, as are the rest of topics on the program, we will have a discussion period after the speakers are finished.

I must insist too that when you get up and make a statement, if you would please use the microphones that are located throughout the room. It's important because our stenographer is taking down notes and we want to make sure we know

who to blame for whatever is being said. So, please make it clear who you are and use the microphones because it's very important.

Also, please restrict or limit your comments and questions today to the speakers and what they're talking about, primarily their topics, because there will be other chances throughout the conference to discuss these issues. There will be a session tomorrow morning and there will also be a session on the following morning that you'll have time to prepare maybe a statement or maybe even show some of your own slides if you brought them along with you. So, please use the mike and please identify yours.

And I would repeat again, please read all of the information that we gave you on mealtimes and meal tickets. If you don't have meal tickets, they are available. If you're staying at the Samoset and you did not receive your meal tickets, please contact the registration desk because they do have them.

Now, that's enough for me. Let's go on with the first speaker. Dr. Greenberg.

BAY OF FUNDY: TIDAL POWER DEVELOPED IMPACTS FROM TIDES IN THE BAY OF FUNDY AND GULF OF MAINE

DR. GREENBERG: I'd like to thank you for the opportunity to be here for the meeting.

What I'm going to do today is give an overview of some of the modeling that I've been involved with, in support of the tidal power studies in Canada. Some of it might be information that you've heard before and there will actually be some new work that we've not completed yet but have been working on for the last few months. Then I will also put in a little bit of a suggestion of what I think might be a direction for future work.

Let's look at a typical little harbor part way up the Bay of Fundy where the tides are typical. This is Halls Harbor where the tides about 25 percent to maybe 50 percent smaller than the areas where they are thinking of developing tidal power. We take a look at the high water shot and compare it with the low water shot and think of how much energy it would take to pump that much water back and forth, multiply it by the factor for the increased tide and increased reservoir. You can get an idea of why people think there is a significant source of renewable energy right at our doorsteps.

The question has occurred, mostly from the engineers interested in the tidal power project: What would happen if you did put a barrier up in the upper reaches of the bay, up in Minas Basin. This is in Cobequid Bay, most of what I'll be talking about will be concerning this barrier because that has the more far-reaching effects.

Anyway, what would happen if you did put a barrier in there? Engineers want the answer because they want to know how much power they were going to get out of the dam. If the tide was going to change at the barrier, they wanted to know. That works into their economic forecasts of whether it's worthwhile building the thing or not.

As a by-product you might also see some changes in tidal regime that might have some environmental impacts. At first

it was thought there was no reason to believe that putting a tidal power dam up here in the upper Bay would have any effects further out. Some of my work and all kinds of other people's work, the original tidal power study in 1969, use models that stopped at the mouth of the Bay figuring that it's quite unlikely that anything is going to happen beyond that point. But that was done before there was a good understanding of what causes the tides in the Bay of Fundy and Gulf of Maine anyway. And we do really have to understand this.

My favorite explanation comes from a tourist brochure in Saint John, New Brunswick, where they claim, "These tides are caused by a combination of two factors; first, the distance of the moon from the earth in this local meridian; second, the facts that the Bay of Fundy opens southwardly, receiving the full force of the tidal currents, which originate in the Indian Ocean." Well, if you think that the Bay of Fundy points toward the Indian Ocean, NASA has been wasting an awful lot of money in satellite pictures.

And the other point about the moon and the meridian and all this sort of stuff is pretty lousy astronomy and extremely poor oceanography. The tides in the Bay of Fundy and Gulf of Maine are caused not by the direct forces of the moon but by the forces of the tides in the deep sea. The deep sea tides are the direct result of the forces of the moon. The directly moon-forced or sun-forced tides on the continental shelves are always small. So it's the tides that hit the edge of the continental shelf that are amplified in the coastal areas on the continental shelf areas.

Well, what makes the Bay of Fundy/Gulf of Maine special? There are coastal areas all the way up and down the coast of North America, but in this area the tides are higher. Well, the phenomenon that causes the high tide in the Bay of Fundy is called resonance, and we'll give you a cook's tour of resonance here with a quick explanation.

If you sit in your standard bathtub and fill it up approximately 8 inches and start to move back and forth, you'll find a period somewhere around one second forward and the next second backwards that will give you a very strong response from the water. If you go a fair amount slower than that, then the water will just sort of move around you and you won't get a big response. If you slosh back and forth a lot faster than that, you get a whole bunch of wavy action and a fairly disjointed sort of motion occurs.

If you're close to the period of the one second, if that's the exact one for the particular bathtub you're in, then you will get a fairly large response. But the largest response is right at this particular resonant period for the amount of water and the length of bathtub you have.

Before you try this experiment, a couple of warnings, if you happen to have those pretty daisies that keep you from slipping in the shower, you're in for a rough ride. And I'm not too sure what the proper period is for the bathtubs in the Samoset resort because it's a little bit different shape, but if you do try it, and take the experiment to it's logical conclusion, be prepared for a larger bill.

Now, for the Bay of Fundy/Gulf of Maine system, the bathtub is the whole Bay of Fundy and the Gulf of Maine put

together. What happens is the experiments -- computer experiments -- as well as observations have shown that the Bay of Fundy and Gulf of Maine combined, as if they were a bathtub open on the end facing the Atlantic Ocean would have a natural period of about 13 hours. Well, 13 hours is a little bit longer than the period that the tides are being forced from the edge of the continental shelf. Their strongest push is coming at about 12 and a half hours. But that's close enough to give you this very strong response throughout the Gulf of Maine and Bay of Fundy. That's why we have to include this whole area in the present model.

Now, to run the model after setting up the grid structure as you see it here, we have measured the tides with deep sea tide gauges on the edge of the continental shelf at seven stations, giving the general tide input along the edge, and we put that forcing on the edge of the model with the proper equations of motion in the interior of the model, and we checked it out. I think we had over 70 tide stations that we were checking around the edge of the bay and some in the middle of the Gulf of Maine and some in central Bay of Fundy as well. And we got a very good calibration of the tide, being able to reproduce the existing tide very well.

With that reproduced existing tide, we then go ahead and say let's simulate, instead of just free flow across a couple of barrier sites, we're now going to simulate tidal power barriers.

Now, in this case we're looking at a tidal power barrier in upper Bay of Fundy -- Economy Point being the principal barrier under consideration. You see, what you do is create a reservoir, and the type of tidal power generation that we're talking about is ebb flow/ebb generation. You have sluice gates that allow the water in and turbines that allow the water out. Over the course of the tidal cycle, If you start out at the beginning, you're going to open up your sluice gate, you're going to fill up the reservoir behind the barrier. Close the barrier. Wait until there is enough of a difference between the reservoir water level and the tide water level to turn on your turbines. Then you're going to open your turbines, generate your power. You'll find that actually you can generate power for 7 or 8 hours out of a 12-hour tidal cycle with the installation levels that we're looking at when these studies were done. Now they're looking at even higher installations, so that would tend to shorten this generation period but probably give more electrical output for a shorter time.

When the reservoir falls to a critical level and it's no longer worthwhile generating electricity, you close everything up, wait for the sea level outside the barrier to be higher than the reservoir level, and then start the cycle again filling up.

Well, what happens when you throw these sort of things into the model? Here we have the red areas or the present ranges depicted high/low on either side of the black line down the middle, and the yellow are the resultant tidal ranges when you put in a barrier up here at Economy Point. And you see that there are changes all the way down Cape Cod, even a very minor change at Hyannis, but the changes really fall off to nothing as you round Hyannis. And also as you go around Liverpool in Nova Scotia,

things have really dropped off to nothing.

But we do have a change, a significant change all the way as far as Boston and Cape Cod. In Boston there's an increased higher high water or decreased lower low water of about 15 centimeters. That change is fairly uniform. The percentage change is not quite the same, but the 15 inch change in Boston progresses to 13 centimeters in Saint John with a fairly even progression between the two, and it gets up to over 20 centimeter in Chignecto Bay.

There's actually a drop in tidal level close to the barrier but it starts to increase again as you move seaward from it.

Now, how do we explain this? Well, the thing is that the Bay of Fundy/Gulf of Maine is not your simple bathtub with one simple period. There are other effects as well. The frictional effects in particular are very important to how this oscillation works.

What happens when we put a barrier in, remember, we talked about this whole bathtub having a free period of about 13 hours. When we start chopping off pieces of the bay, we are shortening the period. And the important parts of oscillation, (just small bits of the Bay of Fundy) correspond to big chunks of period, if you want to look at it that way. And what happens is you're shortening the period from 13 hours to something closer to the 12 and a half hour tidal period that drives the tides. This means that the whole system is now moving closer to resonance and you're getting a more efficient transfer of energy from the deep sea into the Bay of Fundy and Gulf of Maine.

But it's more complicated. There is a drop at the barrier. And what this is caused by is the fact that the Bay of Fundy has a period of its own, and that's about 9 hours. And when you start shortening that, you're taking it down closer to 8 hours, which is even further away than the 12 and a half hour tidal push; and therefore, the amplification from the mouth of the bay to the head of bay is reduced.

In this case there is another effect as well, the friction of the water going through by Cape Split. Because you're getting less water through the barrier, the energy that it would normally dissipate through the Cape Split passage is now not dissipated, so you end up with high water through most of the head of the bay. If it weren't for that, you would see a decrease throughout the head of the bay because of the decreased amplification in the bay, but at the mouth the increase in general overall Fundy/Maine amplification would dominate, and so from Saint John down, you'd see an increase in tidal level. So there are these three effects interacting that give you this tidal change.

Now, the big question is, do I believe it? The answer is yes. How accurate is it? Gee, I don't know. Let's go on a little bit.

Do we believe it? Well, yes. Why? We'll go through some of the different reasons why we might believe these calculations. First of all, we did start out with a well calibrated model that did a very good job of reproducing the present tides. By itself, that is not a good enough reason, because we started out with well calibrated models when we looked

at just Bay of Fundy. But now we model all the way out to the edge of the continental shelf.

Why do we believe this one is better? Well, we can go out and say, "Let's look at the open boundary problem, and we can check." Perhaps if we used some estimated idea of how the North Atlantic reacts, we could say how well these two systems, the North Atlantic and the Bay of Fundy/Gulf of Maine system interact; and if they interact in a way according to the approximate numbers we get, then it looks as if the answers that we're getting are predicting the tide from the tidal power barrier to within one percent. At least as far as the open boundary data goes, this would cause about a 1 percent error in what we're predicting for the tides. So that open boundary problem wouldn't be a problem if we know what the North Atlantic is like. I'll get back to that a little bit later.

There have been other models of the Bay of Fundy/Gulf of Maine system. None that are quite as well calibrated as this one that do give the same sort of results. Chris Garrett of Dalhousie University, has done a model where he looked at chunks of about 20 kilometers (a model with 20 kilometers grid size). Now, you'll remember that we were looking at a fine grid of less than 2 kilometers for the finer grids at the head of the Bay. We had the bigger grid size in the Gulf of Maine, but we did have the Bay of Fundy well resolved.

Now, when he took off one chunk (one grid square) in the head of the bay, he was also finding a decrease in tide at the mouth and an increase of tide further out in the Gulf of Maine. George Duff, University of Toronto, had what might have been the ultimate model, but to make sure that he didn't have an open boundary problem, he took his boundary from this side of the model, went towards Newfoundland, somewhere over towards Greenland, and then over to England and then across to Africa, down to South America, across up, ignoring the Gulf of Mexico, and back up to Cape Cod to figure out what would happen if you put in a barrier up in the upper Bay of Fundy. He got just about the same sort of answer. Although he had a very poorly calibrated model, he was getting the same sort of thing with a decrease of tide at the barrier and increase further out in the Gulf of Maine.

Of interest is that in this particular model, he found that the tide out along the open boundary did not greatly change, which is important for the assumptions involved in my model where we assumed that the tide would not change out at the open boundary. So this is another sort of check as well as our theoretical ideas of how the North Atlantic and Bay of Fundy might interact.

I've already gone over why we think we now understand the Bay of Fundy/Gulf of Maine in terms of its resonances and its frictional characteristics. So now we think we have a theoretical basis for understanding what is happening in the Bay of Fundy/Gulf of Maine system and saying that, okay, these changes can be understood in terms of what we do know about the bay.

The model has also undergone several changes since its first inception. It started out in the early 70's as my thesis work at the University of Liverpool. When we look at the

first outline of the model as it was, pay particular attention to the detail we had in the Upper Bay. We were missing parts of the end of the bay. The fine grid in the final model is further up the bay. We stopped the first model short of the continental shelf in places, and it doesn't go very far up and down the edge of the continental shelf.

Compare that to the present model in the upper reaches. We have found the finer grids is very necessary. Also, out on the shelf, we can see the areas that were added. What you don't see in the slide is the increased complexity of the arithmetic equations that we were using, where we added additional terms and we started to take into account the fact that the area underneath each of these grids squares was constant on a Mercator projection which would mean different areas as you work south, and also the factor for rotation of the earth changes as you go from north to south. So we had these variations built into the model.

All of these cause some changes in the predictions that were being made for the tidal power barriers, but they were all the same nature of change, and the differences from older predictions not all that great. I think the changes were from about a 6 percent change in Boston to a 10 percent change in Boston, and now we think we have just about the ultimate in what we can do with a model, at least a 2-D model in terms of how many terms can you put in the equations and how accurate can you get it for this type of model.

There is one other factor though that is always going to cast doubt on this, and that is what I talked about earlier: the response of the North Atlantic. We are never going to really know how the North Atlantic responds. And if the North Atlantic and the Bay of Fundy/Gulf of Maine should somehow become better tuned to each other as the tidal power barrier dam is built, then you might end up with changes different from what are being predicted here. You would end up with changes at the open boundary. I think it's going to be very hard to get a better handle on what is happening in the North Atlantic and try and figure out the resonance characteristics of the North Atlantic. It's just a very difficult problem to handle theoretically, observationally, or numerically for that matter.

So what we have come up with is basically a feeling that the predictions that we are making are probably good to plus or minus 25 percent of the change predicted. So if we're predicting a 10 percent change in tide, then we think that we're going to be 7 and a half percent to 12 and a half percent is probably as good as we're going to do, and we think that any numerical model is going to have problems doing any better than that.

I might add another note on the model of George Duff, although he did try to include the whole area, it is very difficult to see that he has actually got the proper response of the North Atlantic in his model. He has a very poorly calibrated model. The tides were coming in hours differently from the timing that they should have had for the Bay of Fundy and Gulf of Maine. And that type of model is not really applicable because you really have to have the whole coastal areas around the North Atlantic, all the continental shelves accurately modelled if you're really going to use it for this sort of problem, and that is really

beyond the scope of even the higher powered computers in existence today.

One further test we have done and this is something we've been working on in just the last couple of months. Over the course of 18.6 years, the tide amplitude is varying by 3.73 percent. So if you had a tidal amplitude on average for your main lunar tide of 100 centimeters, every 9.3 years it would be 3.73 centimeters higher, and then 9.3 years later it would be 3.73 centimeters lower.

Now that is what is hitting the edge of the continental shelf along the northern seaboard, that sort of variation. Now, we wonder whether you see that in the Bay of Fundy/Gulf of Maine, and you think you would not, because it is such a frictionally damp system. You would expect whatever is hitting it out in the edge of the continental shelf to be somewhat reduced by what is happening in terms of friction. And in the observations we see. We've put together strings of records that are 19 years long. They are not very long when you're thinking about an 18.6 year period, and you've got 19 years of record, and you're trying to figure out what the amplitude of a signal is over that time, and it's only 3 or so percent of what you're looking at.

But anyway that's what we did, and we analyzed that, and we see we were getting pretty similar sorts of numbers, perhaps increasing from Saint John to Bar Harbor, and onto Boston as to the response that you're getting in the system. Now, if the numerical model is doing its job properly, then we should be able to get somewhat similar results out of the model. We should be able to force the tide on the edge of the continental shelf a similar amount and check to see if we get the same response.

Now, here a bit of theory comes in. We might be forcing it at 3.73 percent or there might be a bit of interaction with the Atlantic and perhaps it should be 4 percent. There is a long bit of theory that we ramble through why the interaction with the Gulf of Maine/Bay of Fundy might actually mean you're driving it harder to get less response, but anyway it could be a 3.73, or 4 percent -- variations that you could be driving the Fundy/Maine system with.

The results from the model are almost embarrassing. Here we're within one and a half parts per thousand of predicting what this is. We see the same order, and the reason for the order is that most of the frictional dissipation in the Bay of Fundy/Gulf of Maine is up at the head of the Bay of Fundy, up in this direction. So at that end you get less of a response. At Bar Harbor you get a little bit more. At Boston end a little bit more. But it's all quite reduced from what is being pushed, be it 3.73 percent or 4.0 percent. And this is from numbers that are pulled out of let's say one cycle of tides, and if you ignore the last digit here, which perhaps you probably should in terms of what we can really expect for accuracy, and in fact if I were thinking of the data, I would really wonder about this second decimal. It agrees so well with what we've got here, say 2.2 to 2.3 (model) and we've 2.3 (observation); 2.4 to 2.6 (model), 2.4 (observation), 2.6 to 2.7 (model), 2.6 (observation). As I say, it is almost embarrassing to get that sort of agreement,

but we'll take it.

Now, if we can't get any more accuracy, then what sort of tact should we take? Well, we have to say, Let's look around and see the sort of change that we're predicting at, say, Boston -- and that's the favorite example that we all take, it may apply to anywhere else around but Boston is such fun (to flood Logan Airport). I have been told that Logan Airport does have problems. Every five or ten years, approach roads do get flooded when there is a bad storm surge.

But let's take a look at 15 centimeters and say, Is that a problem? Take a look at the variation in tide, on the average the tide at Boston is 1.4 meters, but the higher tides of the year, are 1.8, and the lower, .95 meters. For people that really want to be translated back to the old fashioned English system, that would be a variation in tidal range from 6 to 9 feet.

If you end up with any kind of wind at all, it's nothing strange to see waves that are plus or minus a meter away from mean level. And different from waves, we have storm surges, and that's the sort of thing that might push the water down at Bar Harbor and push it up at Boston. So they are large scale differences in water levels, and these have been measured in the neighborhood of 2 meters (both positive and negative). Compare that with a piddling little 15 centimeters from tidal power, and you can say, jeepers, we've got nothing to worry about. That isn't quite fair. You can say that 15 centimeters really doesn't matter unless the water is already up to your chin, and then it might be important.

As an example, if we consider your normal modest country retreat on Cape Cod, and say that perhaps there is a 1 in 40 beach slope, that is to say that it goes up 1 foot for every 40 feet you come inland, and we change the higher high water by 15 centimeters, and if the property line is limited by the normal high water line is, we have now chopped of a good 6 meters, about 20 feet off the front of his property. Now you multiply 20 feet times of the length of the coastline of Cape Cod times the cost of an acre of land on Cape Cod and probably tidal power might not be worth it, but on the other hand, that might not be the right way to look at it. I don't know how they measure their property there, but a 1 in 40 beach slope is a shallower slope. I think somewhere in the middle might be a better way of looking at it. I won't go into much more of what I'm thinking of as direct impacts, because I think Peter Larsen is going to cover that sort of thing a lot better than I will.

There is one effect that I will talk about, however, and this has come out in mostly loose talk in a meeting that was held in 1976 where everybody was making their first guess of what might happen in tidal power impacts. Chris Garrett was suggesting or throwing out, really, the idea that, jeepers, if you have higher tides, you're going to have higher tidal currents. The tide currents mix up the water. If in the summer they mix up the cold water from the bottom to the top, and you change the surface water level by one degree and that surface water level translated into one degree change in air temperature so that you're cooling your summer down by one whole degree, what would that do for your growing season? Some people took that as an absolute prediction, and that is really not a good way of looking at it. But there is

a little bit of evidence that we can look at.

There are places where there are long-term measurements of sea surface temperatures and long-term measurements of air temperatures. If we look at the annual mean sea surface temperature and the annual mean air temperature, and starting with just the sea surface temperature, and you say, What part of that variation that you see might come out to be? At the same time, what sort of cooling could be explained in an 18.6 year period? So at the maximum of this tidal variation, we have this 2 and a half percent change in tides already occurring. Naturally in nature every 18.6 years is a repeated cycle that I've already talked about. So we push this a little bit stronger. We get this little bit more mixing going up, and perhaps we should see it in sea surface temperature. Well, in sea surface temperature maybe one quarter of the signal at 18.6 years comes at the same time as the pushing of the water and the strength of that 18.6 year variation. So that amounts to about .4 degrees. Well, that doesn't really say that it's caused by it, but it at least might be correlated with it. It looks like it's also correlated with other things that makes it less likely.

Now, if you say that's two and a half percent, multiply that by 10 percent, that could end up being a 2 degree change in surface water temperature. But let's look at it another way. If we look at the air temperature, we find out that in a long-term record of air temperature that only half the variation in mean annual air temperature that there is in mean annual water temperature. So that it looks like the temperature is not translating into air temperature. So it seems very unlikely that this type of thing is going to be a problem.

Also in model studies we are able to very well predict the areas of well mixed water compared to stratified water, and the two don't seem to matter. If it's stratified, it's stratified. If it's mixed, it's mixed. And if we put a tidal power dam in and look at it again, there are only slight changes. Notice here in the Northeast Channel which is now stratified, but the overall areas are not changed. So that shouldn't really matter a lot, in terms of surface area changed.

So, I think I've covered my main points now. Where do we go from here? Well, somebody is probably going to want to take an another swipe at trying to verify or at least reproduce the results that I've reproduced. And that probably is important, but it's got to be done properly. I think really the way to go though from here is to identify the places, the systems and the processes that a change in tidal regime might affect, and how necessary is it to have that one centimeter -- that last one centimeter -- accuracy in your prediction. Because I feel that if you really have to know something to the last centimeter to figure out whether or not you want the tidal power dam built, then you're probably not going to build it. If you say 6 centimeters, or 15 centimeters is important, plus or minus a few centimeters, we can see that is the nature of things. We can pile more breakwaters on or whatever you need for shore protection and figure out that in the economics. But I don't think the last centimeter of accuracy will be achieved, and if it is necessary, I don't think the tidal power plant will ever been built. Thank you. (See appendix)

MR. BRUHA: Thank you very much, David. Now our next speaker will be Dr. Larsen.

POTENTIAL ENVIRONMENTAL IMPACTS TO THE COASTAL ZONE DUE TO THE BAY OF FUNDY TIDAL POWER PROJECT

DR. LARSEN: Well, I too would like to thank you for the opportunity to speak here this afternoon. I think Dave gave, a very good talk with some interesting points. I know I would like some further discussion.

Just by way of introduction for those of who who aren't familiar with the Bigelow Laboratory, it's a nonprofit laboratory in West Booth Bay Harbor, Maine. It's main emphasis is basic research in the productivity of the sea.

I'd also like to start out by emphasizing that tidal power isn't something that is way down the road in the future. It actually exists now. This is the LaRance (phonetic) project in France. It is a 240 megawatt tidal power project that has been operating successfully since 1967. It contains 24 10-megawatt turbines, and has been successful enough that the French are seriously considering one or two other projects which are extremely large by comparison to this project as are the others that we'll be discussing this afternoon.

We'll move now to the Bay of Fundy. In the short time I have today, I can't be comprehensive about the environmental consequences that may result from the proposed tidal power project. I would like to give you some examples of the kinds of things that we have looked at and should be looking for.

Our approach, and I say our approach because it's not only me. I was part of a team of people from the Bigelow Laboratory and several other institutions around New England, including the University of New Hampshire, the University of Rhode Island, Provincetown Center for Coastal Studies and others. We set out to do a scoping study; that is, assuming that the tidal predictions were right or even more conservatively than that, that the construction of a dam at the head of the Bay of Fundy would change the tidal regime in the Gulf of Maine, what sort of ecological environmental consequences might we expect; that is, what might the second order effects be.

And I'd like to emphasize the use of the word "consequences" rather than "impacts." Impacts has a negative connotation, and all of the potential changes that might be envisioned aren't necessarily negative. In fact some might be considered quite beneficial. That's even before you consider the amount of clean power that would come from a tidal power plant.

I would also like to emphasize that the ideas that I express this afternoon aren't mine. They come not only from the team but really hundreds of other people that we've talked to over the years, and these ideas have evolved over the 5-year period that we've been interested in this project, and as you will see, they certainly raise more questions than they answer.

We are principally talking about this proposal in the Minas Basin, although the other proposals too at the head of the Bay of Fundy would have effects on the tidal regime of the Gulf of Maine through the same mechanisms that Dave has just described.

This is the site. You can see it is a very rural area, and from the standpoint of, I think, on-site impacts, socioeconomic impacts in the area, it's probably a very good choice of sites. Of all the research, the majority of research on this project been on-site, behind the dam sorts of things. I'm going to emphasize or mention only the far field effects.

Just to orient you again about the Gulf of Maine, we're talking about sites quite far removed from the areas that I would emphasize where environmental consequences might be felt.

These consequences are the consequences of changes in the tidal regime. This graph brings you down the coast from the Bay of Fundy around Cape Cod. There are two lines. One is the absolute change in the tide amplitude, which is one half the tidal range. You notice this gets small as you go down the Bay of Fundy and then stays pretty constant through the Gulf of Maine.

An important point I think is that the percentage change increases along that same gradient so that you're talking, in the Gulf of Maine, about a 10 percent change in tidal range. As you will see or understand, a number of people's first reaction to this is, So what, you already have a big tide and what's a change of 15 centimeters going to do when up there in the Bay of Fundy the change is that much larger? For one thing, it's a percentage change. Secondly, as you saw at least at the dam site, you're talking about a relatively undeveloped shoreline versus Portland, Maine and south to Cape Cod where you have a very highly developed shoreline.

One of my pet theories is that you have more development on the shore here simply because the tides are smaller. The same amount of variability around the tidal mean can be more easily accommodated by engineering structures. For example, the pilings which piers are built on are made of trees, and then businesses and restaurants are built on those piers. You don't get the same kind of development in the Bay of Fundy. I happen to think it's just because the tides are so high that you don't have trees big enough to make those pilings.

But moving right along, for the purposes of consideration of the consequences, we've found that it's best to talk about the consequences in two different forms. One is those caused primarily by changes in tidal heights, the water levels. Most of them are those that engineering people would be interested in. And then secondly, those caused by changes in the tidal currents. Some of these have more important ecological consequences.

The changes in water level can further be looked at three ways. I'm categorizing the consequences now. Those caused by higher high tides, those caused by lower low tides, and those caused by the absolute changes in the tidal range.

The higher high tides, those consequences are the ones that have gotten the most attention so far and probably will continue to get the most attention because they are the most obvious and the most dramatic. "By land submergence" we mean that a certain amount of terrestrial habitat, present day terrestrial habitat will be submerged at high tide under a modified tidal regime, and will therefore become intertidal habitat.

Dr. Graham Geise, of the State University of New York, did some projections for us on the State of Maine and determined that a 15 centimeter increase in the mean high tide level will cause submergence of 4200 acres of terrestial habitat. This is a strip along the coast of Maine on average 2.5 meters wide. Others, in particular Joe Kelley with the State of Maine, who is here today, has told us that he thinks these estimates might be somewhat conservative and the land submergence might be more in the order of 10,000 acres in the State of Maine.

Erosion will, or patterns of erosion will, also change because now at high tide waves will be hitting beaches at a higher level. Dr. Geise again has done some predictions for us and has determined that beach fronts can be expect to retreat about 20 meters over a period of years. That's about 67 feet, I think, in the English system. This may not be a problem in an undeveloped beach situation with a healthy dune system behind it, but as we know, those things don't occur all over any more, and this may cause problems on beach systems that have been highly developed.

Storm tide penetration, I use the word "storm tide" rather than "storm surge" to mean the highest point the water reaches during a storm event. Barry Timson, of the Mahoosuc Corporation, has done some analysis of storms over the last 40 years and determined that -- I'm not exactly sure of the numbers but I will put them out to give you an idea of the order of magnitude that we're talking about -- that in that 40 years there have been 11 storms which have had damagingly high storm tides. And by looking at the records, he makes that out to be 7.9 feet above the mean water level.

By adding 15 centimeters to the high tide level, the assumption being that a storm passing through the Gulf of Maine will hit someplace at high tide, that number, 11 storms and 7.9 foot tidal height, that number of storms reaching that height now over that same period now increases to 30 storms. So you might expect an increase in damaging storms by a factor 2.5. That's not to say that the storms will be stronger or increase in magnitude. It's just that the penetration of the storm tide will be further inland because of the modified tidal regime.

Damage to coastal structures, I think is an obvious one. I don't have to explain that any more. Loss of archaeological sites is a very interesting phenomenon, interesting in a negative way. Man has historically gone to the edge of the sea, and this includes our forefathers and even Indians in precolonial times. It seems that in the State of Maine, one-third of the identified archaeological sites are in the coastal zone, and this one-third or a total of about 700 sites could be threatened by an increase in the high tide line of 6 inches.

Impacts on sewer system -- again this is not a comprehensive list, but this is certainly an area that will be problematical in certain situations, especially where storm sewers have a very low head on them.

Influence on bridge adequacies. I just throw that in as what might seemingly be off the wall now, but I live on a place where I have to go across a draw bridge to get home, and in the summer when that bridge is always open, it's really annoying. Now, that bridge will have to open more because the high tide is

higher and that means that much smaller boats will require the bridge to open.

These are some examples from around BoothBay Harbor of the way the present tidal regime interacts with the coastal development. You can see this is a normal spring tide. There is no storm events associated with it. You can see there's not much margin for error in some of these situations.

This is a nonstorm. The same tide a month later with a small storm associated with it put the water into the parking lot and this one restaurant had to close down. I just throw these out to show that you don't have to go far to see examples of where this seemingly small change in tidal height could impact the man in the street and have social implications.

In defense of these people -- the criticism is, well, they shouldn't build there in the first place. Well, they are there, so you have to deal with it. But further these people aren't necessarily as ignorant as it would seem. Most of these places are quite old. And just let's say for the sake of argument that they are a hundred years old. These sites were developed a hundred years ago. The sea level in this area has risen a foot in that time. As Dave Greenberg could explain, I won't try myself, in the Gulf of Maine, because of the unique oceanography, increase in tidal amplitude is associated with the rise in sea level. The tidal range has probably increased a foot over that hundred year period. So you're talking a high water mark maybe 18 inches higher than it was when many of these buildings were built. That's something to keep in mind throughout this discussion and the discussion of sea level rise.

The implications of a decrease in the low tide line are not as dramatic as that of higher high tide lines but they are still not inconsequential. We can lose some subtidal habitat. You know, that's the biggest habitat on earth. On the other hand, in certain special cases that might be significant.

With a lower low tide, unexploited stocks of shellfish will now be available to harvesters. Again, you would expect shellfish to come back and reach a new equilibrium. I'm confident that we're not going to cause any extinctions here, but yet many people believe these subtidal populations of principally intertidal species are important as spawning stock to maintain the intertidal populations. So in some situations this could have an impact on resources. The adequacies of channels, docking facilities, turning basins, this sort of thing will be in question. Often times the the margin of safety allowed in some channels in terms of depth is only a foot if it's soft substrate. This would now reduce it to 6 inches and perhaps necessitate a number of dredging projects.

Again, some small examples from a small town. You can see at this normal low tide, this marina operator could have trouble operating. This fisherman cannot go out if the tide went down any more. Again these are small examples, but they are examples of places where people are going to have to compensate somehow. Money is going to have to be spent to do some dredging, to extend the pier or have the fishermen or other users of the marine environment change their habits and plan ahead more because of tides.

Absolute changes in tidal height are extremely

interesting. For example, increase in the intertidal habitat itself. If we're talking about a loss of 4200 acres of terrestrial habitat, you can just make a projection and turn it into an increase of 8400 acres of intertidal habitat. This is potentially salt marsh, clam flats or whatever. To many people this would be seen as a beneficial consequence. On the other hand, in the winter there would be more ice formation because you're going to have more shallow water. Ice is formed very quickly in the intertidal zone.

Inlet modification. This is another subject of this conference. With higher tidal prism, an inlet is going to have to get wider or it's going to have to get deeper. I won't speak for the experts, but if an inlet is stabilized in size, something is going to have to happen to the bottom which has implications for the roughness of the water inside of the inlet.

Degradation of groundwater quality. The potable groundwater in the coastal zone and on islands is a lens of fresh water floating on top of the underlying saltwater. There is a mixed brackish zone in between those two layers, and the thickness of the brackish zone is about -- well, with a rise in tidal range of one foot, you might expect the thickness of that brackish water zone to increase by 40 feet. So in many areas especially in the coast of Maine, where groundwater quality is already marginal, especially in the summer when there is a great demand for it, you could expect further degradation of groundwater quality with an increase in tidal range.

Tidal current modification can also be subdivided into two components: the horizontal fluxes and the vertical fluxes. The horizontal fluxes are caused by moving of the water. You have more water to move in an embayment in a given amount of time now. You can expect from this an increase in estuarine flushing. Another way of looking at this is an increase in pollution assimilation. The water will be flushed out faster now.

On the other hand, a negative side of this is that you have more saltwater intrusion into the estuary, and when it flushes, the larvae of the unique species that live in estuaries may be flushed out. It may be a beneficial thing in the spread of certain species but a negative aspect in the spread of others. For instance, the red tide organism. The resting cysts of that organism can now be transferred more rapidly from one estuary to the next. Down in the Cape Cod region this seems to be a problem. The cysts spread the bloom from one estuary to the next. This would accelerate that sort of process.

Ice once it's formed will be transported further, perhaps more importantly, faster on the stronger currents, therefore, damage to boats and other marine structures may be more bothersome.

Navigation could be impacted in the sense that you have stronger currents now. You're going to have to use more fuel to push a boat a given distance. Search and rescue missions now are based on time of drift of a boat without power in given conditions. Well, now in the same given time a boat will drift further.

Oil spill containment will be made more difficult. Along the Maine coast now, most of our tidal currents are too

strong to use the conventional methods of controlling oil spills. This now would be made even more difficult by an increase in the tidal regime.

Increased vertical flux has perhaps some of the more far reaching consequences from an ecological point of view, especially in terms of the first line item there, the transport of nutrient to the photic zone. As the Gulf of Maine presently operates, in the springtime the nutrients in the photic zone are rapidly used up by the resident phytoplankton during the spring bloom. The bloom ends -- if I can oversimplify, the bloom ends when the nutrients there become limiting. With stronger tidal currents moving over the rough bottom, turbulence occurs, and those nutrients in the photic zone can be resupplied from the deeper nutrient rich water, hence you could expect an increase in productivity in the Gulf of Maine.

The converse of that, in localized situations, this same kind of turbulence could mean that pollutants spilled on to the surface, say an oil spill, will be mixed into the bottom sediment faster, and that's usually just where you don't want those things.

As Dave mentioned, there are implications for surface water temperature. The deeper water that could be mixed to the surface is colder. So you would decrease the surface water temperature. And I guess I'm advised by different people than Dave is, in our areas at least there seems to be a very strong link between water temperature and air temperature. So you could expect an equivalent decrease in the coastal air temperature if the surface water temperature was reduced. This could increase the occurrence of fog, and it could also make onshore winds in the summertime stronger because you're dealing with a greater temperature gradient between the sea and the land.

This is a satellite image of the Gulf of Maine to explain or to emphasize some of this in a dynamic way. Cape Cod here. The coast of Maine, Bay of Fundy and Nova Scotia. This is a thermal image. These different gradations are differences in surface temperature with the darkest blue being the coldest water. As you notice, the dark spots, at least on our territory are around Georges Bank, the end of Nova Scotia and the mouth of the Bay of Fundy down the Maine coast. These are the tidally mixed areas. This represents cold water mixed up from the bottom to the surface. It's in these cold waters where you find the richest nutrients.

It's been determined through thermal satellite imagery like this and other things, that about one-third of the area of the Gulf of Maine is tidally mixed. It's important to remember, though, that two thirds of the total productivity of the Gulf of Maine occurs in the one-third of the area that is tidally mixed. So these are very rich important areas. Increasing the tidal currents may increase the area of these mixed areas hence increasing the productivity of the Gulf of Maine as a whole.

I'd like to leave you with a couple of points to bring some of this into a political perspective maybe and to link it more strongly with other parts of this conference. One is that the sea level in the Gulf of Maine is rising at a very rapid rate, and if you believe some projections coming out of the EPA right now, we might expect this rate of increase of sea level to

accelerate in the next century, and predictions are an increase in sea level from two to ten feet above what it is now. That makes 6 inches in the high tide line seem pretty insignificant.

On top of that as I've said before, there is a relationship between the tidal range in the Gulf of Maine and the height of the sea. So we can expect as this sea level rise occurs, the high tide line will rise at an even faster rate. So what we're talking about here is something that is a rise in the high tide line that is very much likely to happen in our life time and certainly going to happen within any planning time span for major industries or port development or what have you.

The difference is in timing. If everything went rapidly ahead for tidal power, we might be seeing these tidal regime changes in 10 years, 15 years. If tidal power does not go ahead due to these other factors that have already been set in motion, we might reach this point in 30 or 40 years. Either way it's not too early to start planning.

In addition, the greenhouse effect, of course, is caused primarily by the burning of fossil fuels. And the same people that make the predictions say it's really too late to stop the increase in atmospheric temperature. On the other hand, it may be put off a ways if we reduce or even cut out the burning of fossil fuel. So a curious point is that this tidal power project which will raise our sea, our high tide line, and if all the projections are correct, will also offset the burning of a certain amount of fossil fuel. Therefore, it will, to some unknown extent, reduce the time or put further into the future the greenhouse effect. Therefore, it's a playoff here. Maybe by accepting a little higher water, higher tides now, we may be able to in a small way dampen the accelerating rise in sea level.

One last slide which is less true now than it was three years ago when it was published. Until last year, I think, this has been the reaction of most people, and I'm glad to see because of meetings like this one and others that it is no longer the case. Thank you.

MR. BRUHA: Thank you very much, Peter.

I think we'll take maybe five minutes now to get either a cup of coffee or a cold drink, and then we'll come right back.

(A short recess was taken.)

MR. BRUHA: Is there anyone who would like to make a statement or ask a question of either speaker at this time? Would you use the microphone, please, and identify yourself.

DR. FINK: Ken Fink, University of Maine. I have a question for Dave. One of things that's been in the front of my mind for some months now in thinking about this change in tidal amplification, you've obviously worked with this model for a long period of time. I'm wondering if you could tell us something about the history of tidal amplification in the Gulf of Maine, considering a sea level, say, of 10 meters lower or something like that. Would we necessarily have seen a smaller tidal range or greater tidal range? And also, on the other side of that, the future with no Bay of Fundy tidal dam.

DR. GREENBERG: I wish I could have planted that question. I think some of this is going to be dealt with in the rising sea level part of the meeting anyway, but a geologist and

myself got together to do basically geological work, so I'm going to try to describe his bit in two minutes or 20 seconds.

Basically he has measures through time of the higher high water levels up in the upper Bay of Fundy, and we ran the Bay of Fundy/Gulf of Maine model with some ideas of where we thought the mean water levels had changed to see what difference that would have on the high water level. So that we can remove the tide from the record, and he can, therefore, end up with how did mean sea level changed over the centuries. And the paper went back to, 7500 years ago. This is with Dave Scott, Dalhousie University. There is thought that we might try to extend it back to 15,000 years with Doug Grant of Ottawa and do the same sort of calculation.

The type of experiment that you're talking about has partly been done and I've just been telling Peter about this, one of the experiments that we did was 4 meters from all depths and said, okay, everything is 4 meters shallower. I think that made the tides in the Gulf of Maine about 4 centimeters lower, if I remember correctly. We have to look at some of the numbers.

So the correspondence from rising mean sea level to tidal range isn't one for one, which Peter got from some of the older paper of Doug Grant where he just assumed that that's the way it must have been. It looks to be more like a 1 to 2 percent sort of thing. A meter's change gives a 2 centimeter change in range. Does that answer the question.

DR. FINK: I think it does.

MR. BRUHA: Anyone else like to address either one of the speakers at this time?

DR. KELLEY: My name is Joe Kelley. I work for the Maine Geological Survey.

I noted in the original review of the impacts of the tidal power project that turbidity was thought to become decreased because of the increased amount of water in the tidal prism. It's my feeling that turbidity would actually be increased by higher tidal current velocities and erosion of material that just isn't occurring now, will eventually become more serious; and that harbors might tend to fill in more rapidly, as a result of them being a lower spot and the re-eroded muds moving in there. What do you think about that, Peter?

DR. LARSEN: I think you could be right. I'm not sure exactly what you're referring to, but especially in any place where sediments are coming from deposits within the estuary, with eroding cliffs and things like that, I would think yes, that would indeed be the case.

DR. GREENBERG: Let me just add, it depends on what process you're looking at. If you're say your turbidity is the function of tidal currents, the strength of currents, then, yes, it's got to go up. If you saying the turbidity is a function of your tidal prism, then your increased tidal prism might cause some dilution. I don't know who made the original statement. I think the former probably would be the dominant effect.

MR. BRUHA: Anyone else who would like to make a statement or ask a question?

MR. PRAST: My name is Bill Prast. I'm with Atlantis, Inc. We're energy economist, and my question is for Dave Greenberg.

I'm aware of some of the efforts made to promote awareness and interest on the economic quantifications of some of the points which both Peter and Dave made in the U.S., and those responses have been perhaps limited to date, to put it kindly. I'm interested from Dave's point of view whether he sees expanded interest within Canadian academic and commercial circles in quantifying some of the longer range impacts which you've both so well summarized this afternoon, and when that might happen.

DR. GREENBERG: You're asking me to guess on some political type things. I think the way it sits right now is people in their own research interest without a lot of outside funding in Canada got together to do their predictions along common themes. Right now there really isn't a proponant for the scheme yet. Everybody is doing feasibility studies. When there is a proponent, the impact study has to be done. It has a very good basis from what private researchers have done, like Peter and the folks working in the upper Bay of Fundy.

But now, I think they would have to give it to consultants, private consultants to work out. As to take it any further than it's already been taken, then you need a proponent that says, okay, we want it built. And before it's built, there has to be a proper impact statement done. I think some people think that because we've been doing a lot of work that it was just to prepare an impact statement. No, it did offer a nice scientific basis for a lot of good scientific, almost pure, research work that applied to a very pertinent problem, an applied problem. That made the science fun, and that's why I think it turned out as well as it did. But they haven't gone any further than that to do a proper impact statement, and I think that's where we start to turn it over to consultants.

I suspect that a lot of the work that would have to be done to predict impacts in the Maine area or along the American coast would have to be done by American consultants. I don't think it would really be accepted if Canadians are doing the predictions for what's happening in the States.

MR. BRUHA: Yes, sir.

DR. DUNLAP: I'm Dan Dunlap, University of Maine. I'd like to ask Dr. Greenberg. I notice your model predicts most of the tide frictional dissipation is in the Bay of Fundy. Have you looked at dissipation in Maine's estuaries? Should they be included in the model or will they be significant at all?

DR. GREENBERG: One minor correction, and you've stated it the way I've stated it. Actually a lot of frictional dissipation is also over Georges Bank. The tidal dissipation around the coast of Maine is probably locally significant. I don't think it's significant on the scale of Bay of Fundy/Gulf of Maine resonance or on the scale of Bay of Fundy/Gulf of Maine tidal characteristics.

There was an experiment we did very early on where we said, well, what we'll try to do is look at the Gulf of Maine in 21 kilometer chunks. When you try to model something like Booth Bay Harbor with a 22 kilometer chunk, well, that's not going to work. So how wrong could we be? So what we did is we doubled all the depths in an area about 60 kilometers from shore, all the way up and down the coast of the Gulf of Maine, and said, okay, how bad is our prediction because we have poorly resolved the Gulf

of Maine. And the prediction ended up being a plus or minus 1 or 2 percent of what the prediction was with the more accurately modelled Gulf of Maine.

So we think that, as a sensitivity test, tells us that whatever is happening around the coast of the Gulf of Maine, Booth Bay Harbor, whatever, well, yes it's important to Booth Bay Harbor, but we can still predict for Booth Bay Harbor you're going to have your 15 or 16 centimeter increase in tide. That's still going to be there, but the understanding of what is happening locally is not going to be had from a gross computer model covering the whole Gulf of Maine. It should be more local in its extent.

MR. BRUHA: Anyone else? Anyone else have a question or like to make a statement?

(No response.)

MR. BRUHA: I want to thank you both of you very much for your presentations. They were excellent. And we're looking forward to you again on the final day, both of you, and the rest of speakers, because on that day is when we're going to have to summarize this whole thing.

And I want to remind you once again that this is not a decision making conference. This is more an information conference, and we'd like to have your information. I want to make it real clear that this is your conference, and we want you to come forward and give us your ideas, so that somewhere down the line, whether it be five years, ten years from now, someone can look at the document that we're now preparing and can say, have we looked at these items? Have they been carefully analyzed, or are they worth looking at in more detail? And if we can get this out of this conference, I think that it will be very important to all of us because I think it's a big step.

I would like to remind you again that if you would, please, the moderators and speakers please stay, I have some information that I want to talk about tomorrow's session.

Also, you'll notice that some of us have these funny little tags on under our name tags. The white ones are people that are fairly familiar, I hope, with what's going on, and if you have any questions at all about anything, please contact one of us. And, I'm going to ask the speakers, if they would, to wear their tags throughout the conference because you can be more easily identified.

Thank you again, Peter and David, will see you all tomorrow.

(Whereupon, the conference was adjourned, to reconvene at 8 o'clock a.m., Wednesday, October 31, 1984.)

APPENDIX

TUESDAY, OCTOBER 30, 1984

1:00 p.m.

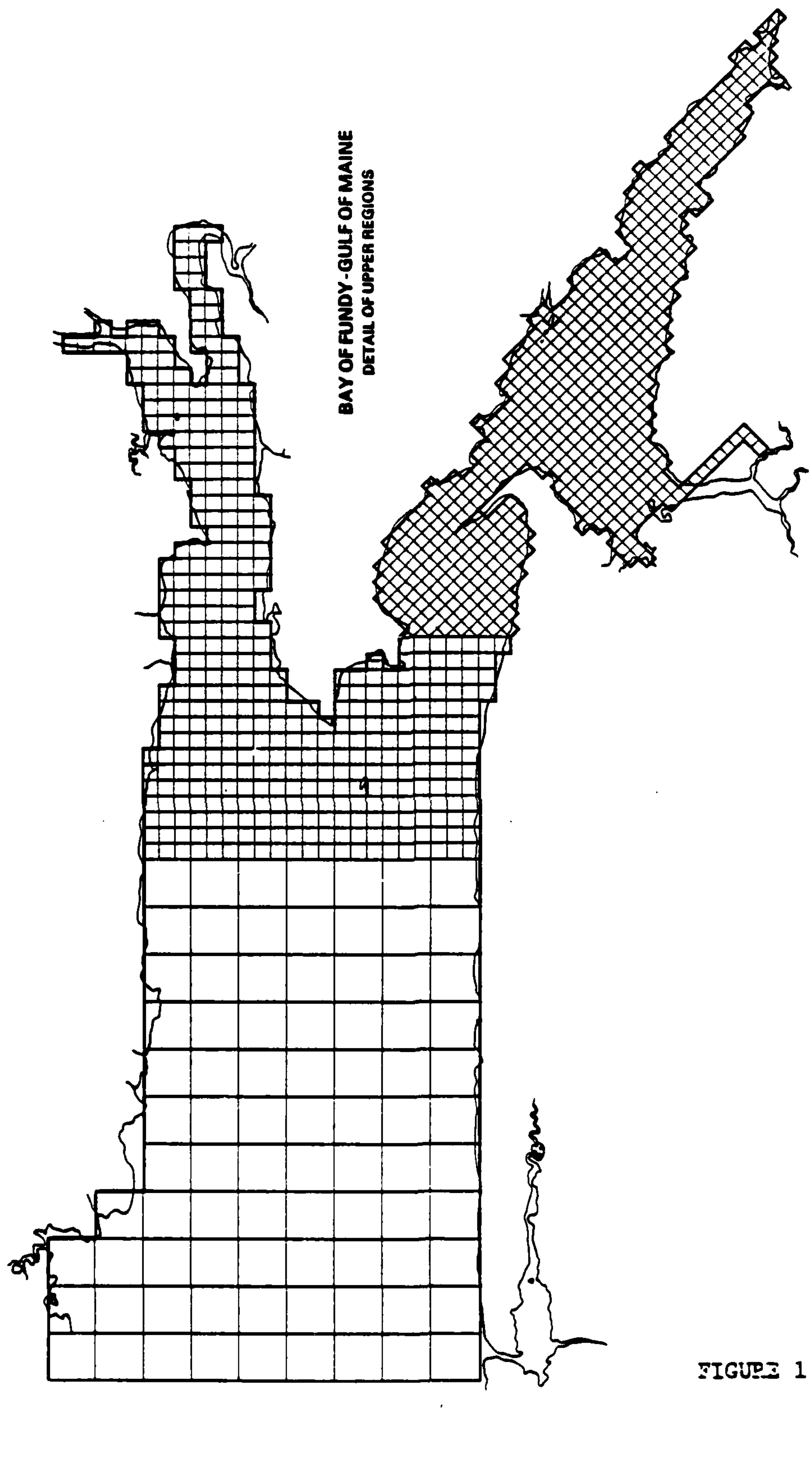

FIGURE 1

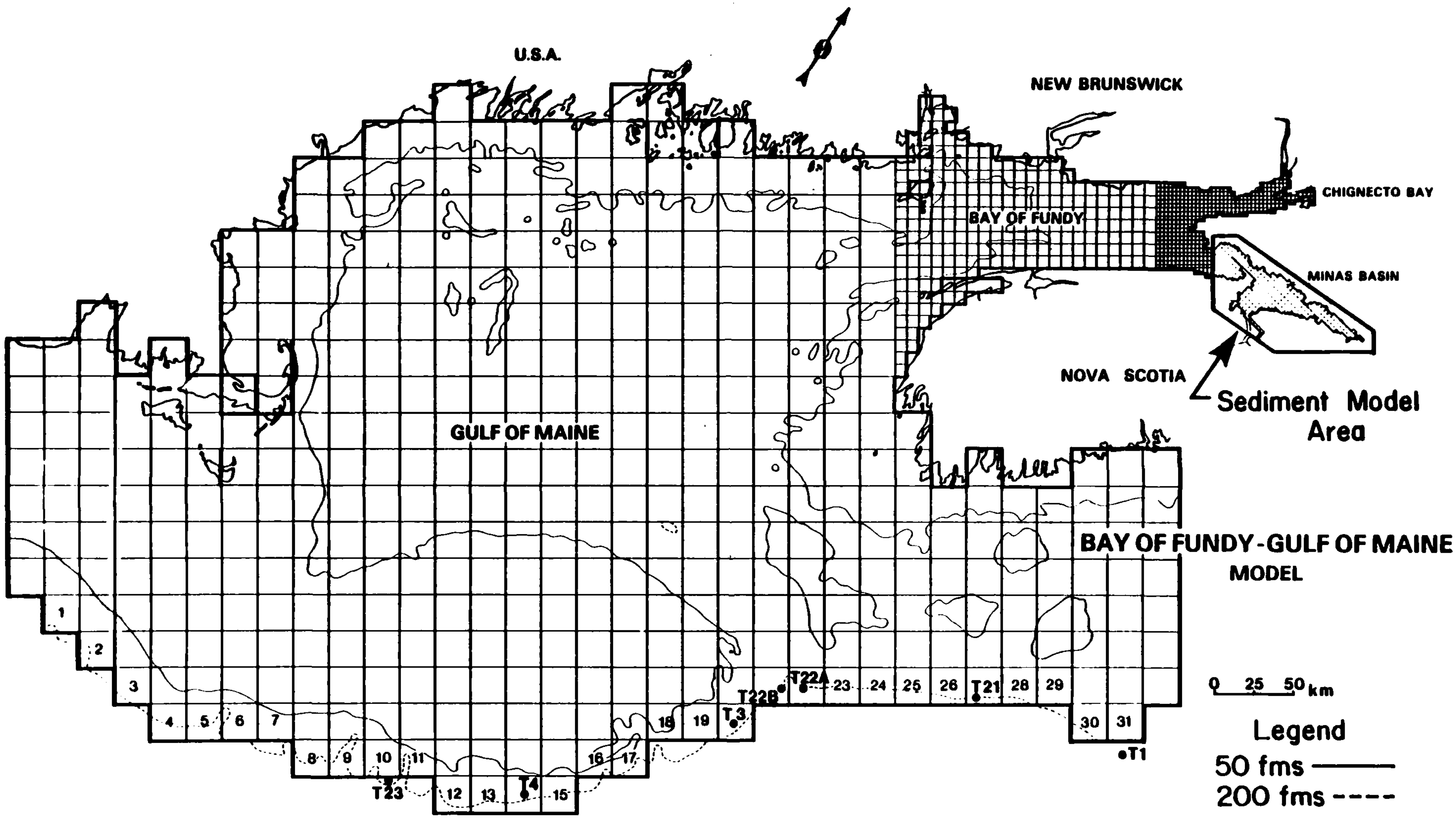
U.S.A.
NEW BRUNSWICK
CHIGNECTO BAY
BAY OF FUNDY
MINAS BASIN
NOVA SCOTIA
Sediment Model Area
GULF OF MAINE
BAY OF FUNDY - GULF OF MAINE MODEL
0 25 50 km
Legend
50 fms
200 fms
1 2 3 4 5 6 7 8 9 10 11 12 13 15 16 17 18 19 23 24 25 26 28 29 30 31
T1 T3 T4 T21 T22A T22B T23

FIGURE 2

Wednesday, October 31, 1984

8:00 a.m.

INDEX

I N D E X (Continued)

PROCEEDINGS

MR. BRUHA: Good morning, everyone. Welcome again. We have a very busy schedule today, as you've all seen from looking at your agenda. So while the people are wandering in, I think we'll get started.

I know there's been a problem with the meals, and let me explain a little bit why. The reason is is because they tell me this is a gourmet kitchen, and everything is done individually. So I'm quoting them by saying they are saying everything is done on an individual basis. Nothing is prepared "in advance." So that's why it's essential that we have reservations and also we have meal tickets so that they know how many people to anticipate to prepare for.

We did make a complaint to some degree for some of us who had a waitress who thought that maybe we wanted to spend more time visiting than eating in the dining room, and so we did formally make that request that maybe from now on they speed it up a little bit. But they did say that you can anticipate -- and I'll repeat this again when more people are here -- that you can anticipate a minimum of two hours for dinner.

I think we should begin. I would like to introduce to you our Deputy Division Engineer for the New England Division, Major Hammond.

MAJOR HAMMOND: Thank you, Tom.

As Tom was talking about the food and the service, I was trying to compare it to the type of food that you can get in an Army messhall, and I guess it's exactly the same, except for two things. And that is the speed with which you can move through the chow line and the type of preparation that they have. Other than that, it's exactly the same.

I'd also like to welcome you all on Halloween day here, and I'm glad that we're having such a good turnout for the conference. The work that Tom has done in preparing this has been outstanding. Of course the turnout particularly on Halloween probably has something to do with the fact that you either want to escape all the trick or treaters or that you want to escape the high rates here during the on season and you came at a good time with this conference being set up in the fall as it is.

This is the first regional coastal engineering conference and we're very happy to be hosting it. It had it's genesis in the last Coastal Engineering Research Board that met on Cape Cod about a year ago. That's a national board that's set up to advise the Chief of Engineers as to the priorities that should be given to coastal engineering research. And the suggestion came up, well, why not have a regional meeting because there are a lot of issues that are more regional in nature and it's good to get people together to discuss those, and also helps us in the Corps of Engineers to realize what some of the priorities are, what some of the comments are, and how we can go from here. We're certainly in the business with a lot of coastal structures, our navigational work along the coast, and we can use a lot of input as to where we should be moving and what some of the future effects are likely to be.

So we're very happy to have all of you here to help us with that task. I think Tom Bruha, as I say, has done an

outstanding job in arranging this and getting things off the ground for the first regional conference. Other people, of course, in the Corps of Engineers that are here to help represent that, Nick Avtges, Larry Bergen, Larry Parente, Fred Ravens. I hope those of you who don't know us from the Corps will get a chance to meet some of these people and give us the benefit of your advice. We're very happy to have you here.

Some of you may wonder why somebody is here in an Army uniform to welcome you to this conference, and that's why I want to take some time today to talk a little bit about the Army Corps of Engineers and how we fit in and our role in working with the civil works program.

We in the Army in the green suits, the active Army, move from position to position very rapidly, don't get to stay anyplace more than two or three years. I've been in New England for about a year, having come from an assignment in Korea with with a troop unit. The people who do the work in the Corps of Engineers are people like Tom, Larry and Nick, the dedicated professionals that we have that do carry on the work, and we're very fortunate in having a fine staff that we have in New England.

Some of the background on how the Corps of Engineers got into this business and why we think we are able to perform a vital service to the nation would be the topic that I'd like to discuss this morning before we move on to the rest of conference.

The Corps of Engineers is really one of the first environmental protection type agencies. This evolved from the years when we were trying to protect Yellowstone National Park. We made the first recommendation that it be preserved and were the first managers of that area before the National Park Service was set up.

We've moved from that era on into the present where right now we're involved in the cleanup of hazardous waste, applying our engineering and construction expertise to meet the challenges faced by the nation.

Historically the Corps' primary civil works emphasis has been on the development and protection of America's water resources. This work has included responsibilities for navigation, shoreline and stream bank protection, flood control, hydropower, water supply and water quality.

The New England Division is one of 14 Corps divisions world wide that execute the missions that we have in support of the armed forces and federal civil works projects. These divisions and their subordinate districts are currently supported by five Corps laboratories that provide the research to insure our methods and materials will function as designed. Models such as this one at the Waterways Experiment Station in Vicksburg, Mississippi -- and I might mention that we have a good representation from that laboratory today, and anyone that has further questions on the work going on at Vicksburg should certainly collar some of those people and learn about what's going on -- and at the adjacent Coastal Engineering Research Center. These are invaluable to bringing state of the art concepts to our world-wide work.

Our headquarters are located in Waltham, Massachusetts, in an old Army hospital, from which we manage the New England program which will probably exceed $100 million in

fiscal year '85. Our civil works responsibilities cover the six New England states, with the exception of western Vermont. The boundaries of our civil works divisions are set up along watershed boundaries. The 13 major river basins and 6100 miles of coastline provide a real challenge for water resource planning.

We have a staff of nearly 600 that includes a wide range of disciplines and skills necessary for the complex missions before us, such as providing safe federal navigation channels and anchorages. That's a major part of our civil works program. This began back in 1824 when the Corps of Engineers was tasked with keeping the Ohio and Mississippi Rivers clear for navigation and directed to secure coastal waterways for vessels transporting goods along the seaboard.

Since that time, the Corps has made improvements to about 175 harbors in New England. This work has ranged from deep draft ports, such as New Haven, Connecticut, to smaller commercial and recreational facilities, such as Sesuit Harbor in Dennis, Massachusetts, where we provided an anchorage area and an entrance channel.

Increased development in shoreline areas makes the effective management of harbor facilities essential. As part of our on-going regulatory and operational role, we have been actively working with communities to encourage the implementation of local harbor management plans. These plans often require that local residents and harbor users reach a consensus for the first time on long-term harbor use. Their final plan assists the Corps in deciding whether permits for proposed development are in the public interest. Plans also help us to decide how to deal with encroachments in federal channels, which is becoming more and more of a problem.

Currently harbor management plans are being developed in Milford, Norwalk, Fairfield, Clinton and Groton, Connecticut. And we see this as an outstanding opportunity for the public to have an involvement in the planning of their water resources, and we're actively pushing it in using whatever tools we have to insure that people get into this business. Sometimes we have to kind of hit them over the head to get them started, but once they get started, they realize the value of it also. So that we have true input in making decisions about whether to grant permits for construction in a harbor area, allowing mooring, et cetera, and also help us clear up any problems that we're having with people trying to encroach on the federal channels.

Our most active navigation project is the Cape Cod Canal. The world's widest man-made sea level canal has been owned and operated by the Corps since 1928. Last year nearly 28,000 vessels used the canal. The 17 and a half mile long federal project saves over 200 miles for ships that would otherwise have to navigate around the often treacherous arm of the Cape.

We recently installed a state of the art radar navigation system for marine traffic control in the Canal. The system allows us for the first time to identify and track vessels through the waterway in any kind of weather.

Another challenge we face in performing our navigational responsibilities is finding acceptable, cost effective sites for the disposal of dredge material. To address this problem, we are participating in several projects to identify

relevant disposal impacts. In addition to our on-going work in the disposal area monitoring system program, we have a five year laboratory and field research effort called the Field Verification Program. This program, in conjunction with the Waterways Experiment Station and the Environmental Protection Agency's Narragansett Lab, is designed to validate the predictable accuracy of laboratory testing. Both upland and open water disposal sites will be studied over a five-year period to observe the impacts of dredge material disposal.

Our Fall River-Tiverton channel navigational improvement project came to a halt due mostly to the lack of an approved dredge material disposal site. The State of Rhode Island rejected our proposal for a dumping area at Brenton's Reef. Both Rhode Island and Massachusetts, however, realize the need for an acceptable regional disposal site, and Congressman Barney Frank has recently taken the lead in resolving the situation. The Corps is collecting data for the EPA on long-term dredging needs for use in EPA's environment impact statement on the regional site concept.

Congressional appropriations in 1824 provided funding to repair Long Beach at Plymouth, Massachusetts. This was the first beach erosion control project in New England. And since that time the Corps has participated in studies affecting well over 150 beaches. We currently have nearly 50 authorized beach erosion projects in various stages.

In addition, our small projects program is very active in providing stream bank protection throughout New England. This project on the Salmon River in Colchester, Connecticut, protected a public highway and a historic covered bridge from further erosion damage.

Disastrous flooding in the early part of the century brought the Corps into the national flood control mission. This is from 1920. New England has experienced more than its share of flooding with storms of record being the hurricane of 1938 and Hurricanes Diane and Carol in the mid-1950s. We've been kind of lucky since then however. But because of those storms, the Corps completed 35 dams throughout the New England area to tame the flood swollen river system, and they certainly proved their value this last May and June.

We have data collection platforms strategically located throughout the region, automated with antennas to send off their signals, and the real time data is transmitted via satellite to our Waltham headquarters. This information allows us to make effective decisions about how our projects should be operated to minimize flood damages. The dams work in consonance with over 75 local protection projects completed by the Corps to channel flood waters away from populated and developed areas. As a result the damages prevented by our flood control system have exceeded the cost of building the projects by nearly three to one. And in this last flooding in May and June which was not even of hurricane value but certainly a severe storm, especially in the Connecticut Valley, the damages prevented were probably in the range of 700 million dollars.

Not all of our flooding solutions are structural. The widely acclaimed Charles River natural valley storage project outside Boston was recently completed. We purchased nearly 9000

acres of wetlands along the Charles River to prevent future development in areas that now provide a natural flood control action. Another nonstructural project underway is in Warwick, Rhode Island. The estimated 100 year flooding event of this past spring and the tragic flooding in June 1982, however, keep us busy in studying options for future flood damage prevention.

Related to flooding are the four hurricane barriers we've built in New England, with the fifth under construction in New London, Connecticut. These unique structures have been activated successfully on many occasions to block tidal surges from inundating inner harbor and developed coastal areas. This one is in New Bedford -- New Bedford on the left, Fairhaven on the right. And we have a channel through the barrier for the ships to get in and out. But a hurricane surge would just inundate all the low lying areas on those two cities and did back in the 1950's. It hasn't been severely tested since it was built. It's been operated several times, just on more limited coastal storms, but should a hurricane strike, it would really save those two cities.

Tide effects on the coastline have long been an area of concern for the Corps. The two poster sessions last night and the workshops this morning on the impacts of tidal power development in the Bay of Fundy are important. The future role of the Corps in studying these impacts is uncertain pending further congressional action. Many of you remember that the Corps studied tidal power development in Cobscook Bay starting in the 1930s under the old Passamaquoddy project. The project we studied was a lot smaller in scale than the Canadian proposal, but we'll certainly be following related activities closely.

Increased development in New England has resulted in a significantly increased work load for our regulatory staff. Corps permits are required for the placement of fill, for construction and dredging activities and wetlands in the waters of the United States. Our issuance of nation-wide permits or general permits for the states will serve to eliminate some state/federal permit process duplication while still affording a high degree of review and environmental protection.

And I might add while I've got you all here that we can use your help, anyone that's aware of any filling in wetland areas that you suspect may not have gone through the public review process, please let us know. We have a very capable regulatory staff who will be most happy to come to your area, but we can use everybody else's eyes and ears to help alert us as soon as possible to any problem that's going on in this area. We'll get out there, issue a cease and desist order; if something is going on that shouldn't be going on; right away and minimize any damage to the environment. But anybody noticing anything that you have any suspicions about, please give us a call, and we'll be glad to look into it, and we would greatly appreciate your help.

As the federal engineer, the Corps is called upon to assist other federal agencies with our expertise. Our work for the Environmental Protection Agency is a good example. We're monitoring the construction of waste water treatments plants under our grants program.

We are also assisting EPA with design and construction support to clean up hazardous waste sites under the

superfund program. Our first major project is the Resolve site at Dartmouth, Massachusetts. The lagoons of toxic material leaching into the soil here are being solidified and removed under a $5 million contract managed by the Corps. The first truck loads of material left the Resolve site last week for an approved hazardous waste dump site in Ohio, where the Ohio EPA was looking at it to make sure that the material being trucked in wasn't something that they were not going to be happy with. And the reports back were that it did not have a greatly objectionable odor and was acceptable to be dumped in that hazardous waste site.

Our primary mission has always been, and remains to be, support of the Army and our nation's defense. We perform maintenance and construction projects for Army facilities in Massachusetts and at Pease Air Force Base. The work we perform for the armed forces, other agencies, and national civil works requirements combine to prepare us for mobilization on national emergencies. And that's the reason that we have someone here in the Army working with the Army Corps of Engineers because we provide a mobilization base; should we be called upon in such a national emergency.

Through these experiences in combat and in protecting our national resources, the Corps is able to maintain a highly professional and flexible organization ready to stand behind the Corps motto: Essayons, let us try.

Again I'd like to welcome you all to the conference. Please get to know the Corps people here. We're after your input to help us know where we go from here. This is an information gathering and information sharing type conference. We're very happy to host the first regional coastal engineering conference, and I'll give the podium back over to Tom to discuss a little bit more exactly what we hope to gain from this. Thank you.

MR. SMITH: You don't get Tom at this point, you get John Smith. I'm with the Corps' New England Division, and I'm in the Coastal Planning Office.

My subject is the purpose of the conference. I think when they handed out assignments, they didn't want to lay too heavy a burden on this person. The purpose of the first regional coastal engineering conference. In an attempt to get a little profound, I went to Webster's dictionary last night. I figured there would be no help on the first four words, so I went directly to "conference," and not surprising, it comes from from the Latin "conferre," to bring together. Conference: Formal consultation or discussion or interchange of views, also a meeting therefor. I think that pretty well describes what we're doing here. I think it's fits right into our description of our endeavor.

We certainly brought together. What we have brought together is a very impressive cross section of experts in the field of coastal development and coastal processes. The discussions, interchange of views, consultations, of yesterday and what we expect today and tomorrow are going to afford us the opportunity to learn how others have approached and solved problems that we may become involved in or are involved in.

If there is one single failure that is common to all science, it has to be redundancy. I wonder if there is a single

person here who has not approached a problem on a particular subject and first with a rigorous search of available information, it then progressed to a point where they felt they were knocking down new frontiers, and to find out somewhere along the line that somebody else had already covered or was concurrently covering the same material, the same ground.

This will probably be a fact of life as long as there are two scientists left on earth. But to minimize the lost time and effort, all of which translates into money, we must do all we can to learn what others in our field are doing, how successful they are, and at what established dependable plateau a particular line of research is at. Ideally we would all like to start from the highest level of knowledge which has already been achieved by others, and then we would like to proceed upward from that point.

This conference will allow you to meet face-to-face with your fellow scientist and learn the state of the art. Learn. I think learn is precisely what the conference is all about. To learn what our fellow scientists are up to, and to learn the state of the art in the various facets of coastal engineering.

Tom Bruha has certainly made the learning process as painless as possible by selecting Samoset University here, so my advice is in four simple words -- learn and meet people and enjoy. Thank you.

MR. BRUHA: Thank you, John, for those kind words, and also the Major. But as we all know this is not done by any one person. John happens to be the Chief of the branch of which we all work, and I would like to take this opportunity right now to thank the people who work with me, my staff, and of course the people that are assisting us from the Corps, from our office that are over and above just the principals that you're hearing from right now. So believe me there is a lot of effort by everybody, and I thank you everybody for that.

Let's go on because we have a lot of things to talk about this morning. I just want to briefly go over your agenda and to let you know again exactly how I think it should be run, and what we should be doing at different stages. As you can see from looking at your agenda, there is a moderator for each one of the major sessions, and I think what's important to realize is that after each session is, not only a break, but also a discussion period.

Now I want to reemphasize again the importance of this discussion period. This is where we're going to get all of the feedback from all of you people from your conference. If you have anything to say relating to the topic at this particular time, during the discussion period, now is the time to do it at this time. You will also have an opportunity later on on Thursday to bring up other subjects and other topics during a discussion period. We're going to open it up to the general public to anyone who wants to make a statement, anyone who wants to express an idea or concern, and I'll mention again that this is being recorded and I am hoping that I'm going to be able to get a copy of this to everyone that's attended the conference. So like I say, if you're looking forward to it, be sure you have your name in the registration book so we can send you copies of everything.

There are a few other announcements that I'd like to go over. There is a dual session that will take place. So when this occurs, if you'll look on your schedule at page 3, you will see that we have session A and session B. There will be a short break after the discussion period on the Sea Level Rise, a 5-minute break when anyone who would like to go upstairs to the Ebb Tide Room to listen to the discussion on Planning Concepts of Marinas and Maintenance Dredging. There will be a session here and a session upstairs. So if you want to listen to the one upstairs at this time is when I'd suggest you go.

The other thing is that we are having a luncheon today at noon, and it's not down in the main dining room. For those of you who have tickets, conference tickets, it will be right next door in the room right next to us is where it will be located and starts at noontime, and if you don't have conference ticket and you want to join us, I will try to get you in if you want to see the receptionist outside. I'm not sure if we're too late or not. If not, you can always go down to the regular dining room and have your lunch.

There will also be a couple of handouts available to you. For the evening session tonight, I want to encourage as many people as possible to come. We have a pretty good program, a very good program as a matter of fact, and I think out of respect for the people that have prepared it, I'd like to see as many of you come as possible. We will have a handout available for you this afternoon regarding the evening session, the speakers and what their topics are. And it's going to be held right down in this room, and it will begin at 8 o'clock.

So I think -- oh, yes; there will also be another questionnaire that we're going to prepare which I hope we'll hand out tomorrow. It's a questionnaire on the conference itself. We'd like to get some feedback from you, either through the discussion period at the very end of the last day or through this questionnaire as to how you feel about the conference, whether it was worthwhile, whether we should do it again with somebody else maybe hosting it. So, please, when we give you the questionnaire, if you would fill it out and either give it to the receptionist when you leave or mail it to us at our office, either one, it doesn't make any difference. So I think with that we'll go on with the first session. We're pretty much on schedule. That's not too bad.

Our first moderator is Cathy LeBlanc.

BAY OF FUNDY

MS. LeBLANC: The first session that we're going to have this morning has a general title of Bay of Fundy and there are three speakers, and they are Dr. Kenneth Fink from the University of Maine, Dr. James Houston, the Chief of the Research Division at WES, and Mr. David Keeley from the Maine State Planning Office.

We're going to emphasize again that they want these things to be on time because we're going to be running into lunch. So the first speaker is going to be Dr. Kenneth Fink and his topic is Impacts on the Maine Shoreline.

IMPACTS ON THE MAINE SHORELINE

DR. FINK: Thank you, Cathy. Good morning. My talk will address the impacts of the Bay of Fundy proposed tidal range increase on the Coast of Maine. I'd like to preface my remarks by acknowledging a lot of my co-workers, including students and other faculty members from other universities in New England.

My talk will address the impact of the tidal range increase on the Coast of Maine, more specifically I'd like to talk about the beach systems of Maine and the impacts on beaches, particularly the undeveloped beaches. The conclusions that I reach will be of two types; one dealing with the undeveloped shorelines and the conclusions associated with the beaches that have stabilized shorelines. I'll try to indicate the differences between those two.

For undeveloped beaches, we have had significant natural variability occurring over geologic time, over historic time and going on today in such a way that the increase in tidal range that has been predicted will have probably little obvious impacts on those undeveloped shorelines, and we'll get into the reasons as to why that is the case. In the second instance where we have stabilized shorelines, we can anticipate an impact there primarily due to the stabilization.

Developed shorelines such as Old Orchard Beach will be one of those we can talk about a little bit later, although Old Orchard Beach happens to be one of the systems, even though it's very heavily developed, that will probably show the least impact along the entire coast, in contrast to what was stated in the Bay of Fundy tidal range report that's just been put out by the State Planning Office. It was not a good choice.

I'll review some of the basic details of the beach systems of Maine. There are bay head barrier systems or barrier spits anchored by rocky headlands. They are usually contained or confined within bedrock promontories or bedrock headlands. The systems are sand starved. You can see that the rear area of these has been a former embayment, small sometimes. It's been filled in with marsh, now dominated by Spartina patiens

The orientation and accumulation areas for these beach systems is not a random event. We've done a vector analysis of the shoreline orientation with regard to the dominant wave approach direction, and we can see the principal alignment or the orientation of the beaches in terms of wave approach direction. This is your average northeast storm approach direction and here is the average southeast storm approach direction. One can understand very quickly from an analysis such as this as to why it is that southeast storms, even though they are smaller in magnitude and lacking the high winds, don't have the wave energy of the average northeaster. You can see why the impact is so significant on Maine's shoreline.

The beaches are aligned to this dominant or prevailing wave approach direction, even though the beaches themselves may be quite complex in some details. I need to emphasize, as well, the low energy aspect of the coast of Maine. We don't always think of the coast of Maine as being a low energy environment. However, if we take a look at nearshore wave characteristics for four different areas, you can see where the

North Atlantic, based on hindcasting techniques, is a fairly low energy area, not too dissimilar from the Gulf of Mexico. That's an important fact to keep in mind. The storm events themselves are punctuation events. They are discrete, high energy events that hit as pulses along the coast of Maine. The rest of the time we're dealing with a low energy environment.

In talking about the natural variability, we want to take a look at storm surges at the natural seasonal variability of mean sea level, and at the historic and the geologic change of mean sea level. We'll also look at shoreline change characteristics and summarize those at the end.

Storm surges such as this one on January 9th in 1978 have been well documented along the coast. In general we're not talking about significant levels of water. A recent study by the Corps, in Stone & Webster, which looked at the impacts of the storms along the coast of Maine revealed something very interesting. If you take a look at the frequency distribution curves for the storm tide elevations for southern Maine, it's obvious that there is a general decrease in the expected storm tide level as you go from Portland to York; that is, going southerly along the coast of Maine.

If we look at the record of the annual peak tide events -- and these elevations, by the way, have been adjusted to 1975 sea level by the Corps of Engineers -- we can see that we're not dealing with a large number of events over this particular period of time. Despite the fact that we'll have a 15 centimeter increase on the high tide end, we still have to deal with that window of time when the storm itself coincides with one of these maximum spring events.

If we take a look at the data presented in the Corps of Engineers report, you can see that there is a hundred year level of 9.6 feet, a 50 year level of 9.3, and then the ten year level here of 8.6 feet. You can also see that in a probability plot of these data, we have two populations present. A different approach is to take the highest 99 tides that have existed over the period of record from Portland, all of these data refer to Portland, and in doing this we have a much larger data base. We find that there are a few years where the actual peak tide event might have occurred more than once within the year.

So to take only one annual peak tide event seems to reduce the data base that you're dealing with and is not presenting an accurate picture. As a result, we took the top 99 levels and you can see that we get a somewhat different picture. The 50-year level increased to 9.4 feet rather than 9.3. And you can see there is a drop in the 10-year level from 8.6 to 8.5.

It becomes obvious that you still are dealing with two populations in terms of the peak tide event. By plotting this on an extremal probability paper as an extreme event simply because the data are so skewed, we find we get a much better plot of these data, and we can see the change of the 100-year level to 9.6 feet, the 50-year level is still 9.4, very firmly fixed, as opposed to 9.3. So we've gained a tenth of a foot by looking at the data in a slightly different way, or actually looking at more data, we should say. The 10-year level is 8.5 feet, a bit lower than indicated by the Corps and reported in the Larsen et al. report.

An even more interesting change going on is the annual variability. In this case we took 69 years of data we had from the Portland tide gauge and averaged these data. Despite the fact that there is a secular trend in there, we assumed the trend affects, equally, all months of the year, and this is the annual change you can see in the mean sea level position. We're seeing a .23 foot change occurring every year. You can see that the time of year that this is taking place is in the spring and early summer with a second peak in the October-November area.

To give you an idea of the data that went into that distribution, we're looking here at just three years of data. You can see that there is quite a bit of variability from one year to the next. The important thing is that when you actually average a large data base, such as this, you get a much clearer picture of the variability of mean sea level that's taking place annually.

The seasonal variability is due to these factors that you can see listed here. Most people are familiar with them, and it's clear that they are the factors that are influencing the curve you saw describing the annual variability.

Another interesting aspect of the annual variability is seen by looking at the maximum change that takes place between that lower stand of mean sea level and the higher stand for the year. Looking at these for the entire period of record, and we can see that we get an average change of .47 foot or 14 centimeters of change, on the average, annually. And that's a mean sea level change. The beaches have responded to this, and have established an equilibrium accordingly. So we're dealing with a range of change of mean sea level, not just the high water event. Therefore, the beaches are already responding to a seasonal significant change.

If we do the same sort of a plot as before, in terms of the annual change in the monthly extreme high tide for Portland, you see a similar variability over the 69 years of record. So again, the high water line, in terms of the monthly extreme high tide over 69 years, has undergone a half foot or so of change.

If we look at the record for annual mean high water between 1912 and 1978, you can see the changes that have taken place on the average. I want to point out in particular the change that's going on for mean high water between 1965 and 1980 due to natural variability. There is almost 25 centimeters of change occurring within a time period 1965 to 1980, a little bit longer than that proposed for the Bay of Fundy tidal dam.

Now, if we move to the historic record of sea level for the coast of Maine, this is a record that most of you are familiar with, we can see that we're dealing with a change that's occurring at the average rate of 23 centimeters per century. If we filter out the 18.6 year cycle, we can see the sort of change that's occurring. This makes the record somewhat clearer. Over this last century we've had significant change in mean sea level. And it's the mean sea level that's going to have the greater impact on the shoreline recession rate or the erosion potential for any particular system. Much more so than what the reach of the high water is going to be, as we'll see.

Let's look at the Holocene record of sea level in the midcoastal part of Maine. A basal peat core from the area

behind Popham Beach, Atkins Bay, produced this result. This record, by the way, we have the oldest date found along the coast of Maine, 6770 years before present was the date on that, and you can see it's at a reasonably shallow level. We had another core in this area which seemed to confirm the same general trend that we've indicated here, in contrast to some of the other relative sea level curves for elsewhere in the New England area and Maritime provinces. The rate of change indicated over Holocene time, that is, averaged over 7000 years, is on the order of 4 to 6 centimeters per century, not a particularly high rate.

We know that there has been an associated response on the part of the beaches in terms of a landward retreat as evidenced by tree stumps that occur in the low tide area of the front sides of the beaches, such as Ogunquit Beach, where we have peat actually cropping out after major storms. There has been one date taken of a peat unit like this at Fortunes Rocks Beach which indicated a horizontal offset, that is, minimum horizontal offset on the order of 40 centimeters per year.

To summarize some of these natural variability features I've been describing, here is the list we've run through. We haven't talked yet about historic shoreline change. This is where we can see the culmination of all of these natural variability effects, both in the long-term sense as well as the short-term. It's important to point out that this annual variability is based on a length of record of 70 years and is taking place on a yearly basis. The change is plus or minus 14 centimeters that's taking place every year. And this is mean sea level again, not the height of high tide.

The rise in mean high water that took place between 1965 and 1980 is on the order of 25 centimeters and this is occurring in two decades or less. Historic sea level rise, 23 centimeters per century, is occurring over decades. The average Holocene sea level rise rate is 4 to 6 centimeters per century. Our present rate of sea level rise, as indicated by tide gauge data, is 4 to 5 times greater than it was over the 7000 years of peat records that we have to date.

Now, we want to look at the historic shoreline change. We were able to look at data that included aerial photographs from 40 to 45 years ago as well as charts dating as far back as 200 years. The scale we're looking at is a matter of years. The summary of the shoreline change data show that, in general, we can anticipate a shoreline recession rate on the order of 20 to 70 centimeters per year, keeping in mind that the peat date from Fortunes Rooks that we looked at before indicated a horizontal offset. With any kind of shoreline change, we have a vertical component and a horizontal component with a net angular retreat as it encroaches on the land. The horizontal component was 40 centimeters per year based on one date, indicating that we're in the same range that we see for the historic shoreline change.

We can see the shoreline change patterns in many of the locations along the coast of Maine. It's clear that where we find a frontal dune ridge, we have a former shoreline position. I need to emphasize that despite all of these changes, the variabilities that we've been talking about, we have accretion occurring along the coast of Maine in various locations. This is

due in large part to the fact that we have sand systems confined between rocky headlands. We're dealing with swash aligned systems and sand starved systems. The sand is recycled very efficiently by the generally prevailing low-energy conditions. Supratidally we may have a somewhat higher energy situation in terms of wind transport of sand. But there is an excellent record of these shoreline positions.

We've looked at historic shoreline change along the coast of Maine. This is Seawall Beach, and you can see that we can recognize periods when we do have a landward retreat of the coast in response to an increase in the mean sea level position. There are also other factors involved in this; just as Dave Greenberg mentioned yesterday, nothing is simple. The same case is true here. We have to look at the beaches of Maine, not only on an individual basis, but at site-specific locations along the beach as well, in order to get a true picture. The reason for this is that one of the areas where we find the greatest activity occurring is here, where the inlets are located at the spit ends of beaches. These are the areas that experience the greatest degree of change. Another area where we find significant change is where we have a cuspate foreland. These are usually due to some sort of intertidal ledge area or an island offshore which serves as a focal point for wave refraction patterns and thereby causes an accumulation of sand in the shadow of that area.

I might mention we've recognized and documented seven stages necessary in the development of frontal dune ridges which is a dominant morphologic feature along the coast of Maine that is a record by which we can recognize the shoreline recession in response to natural variability factors. The other feature that is most important in terms of morphological response is in the backdune area, parabolic dunes. Both are extremely important in terms of barrier maintenance mechanisms.

When it comes to an increase in the high water position from the Bay of Fundy dam, we're talking about the ability of Maine's beach systems to maintain their supratidal elevation, or position, or sand volume with respect to this change in the sea level position. And it's the mean sea level that's going to be the primary factor in causing this roll back or this retreat of the beaches themselves.

In the various areas here you can see that there are many different processes involved. In the case of ridge and runnel systems, wind and waves transfer material onto an accreting berm. The wind then transfers the sand from the berm and the upper part of the beachface to build a frontal dune ridge, vegetation plays a significant role in this, as well.

Overwash is often associated with a slight increase in the high water level. We have to recognize that overwash is a very important barrier maintenance mechanism. It's not as important in Maine as most of the other processes that are active, but nevertheless, if we do end up with a 50 centimeter increase in the high water position, we can anticipate a slight increase in the amount of overwash events which are essential in terms of barrier maintenance.

In looking at our shoreline change maps, another point that emerged very strongly is that, although we may be losing sand in some areas on any particular beach, we can look to

other portions of the same system, and we can document general gain. What this is telling us is that the sand, in general, is not being lost offshore, it's retained within the system. It keeps returning despite erosion, and we can be losing sand along one portion of the beach but we gain it somewhere else.

This can be seen in a sweep zone profile of Ogunquit Beach. We can see the ridge and runnel features that are migrating onshore in this profile. The lower most profile here on the beach in this composite shows the 1978 storm. You can see that most of the erosion is taking place on the upper part of the profile, and the sand is redistributed into the lower intertidal area, then brought back by onshore migrating ridge and runnel features which then form the perennially accreting berm adjacent to the dune. You can see the same events at Popham Beach. We can see the sand volumes in the time series here constantly being worked onshore because of prevailing low energy condition. It's only during the storms that a lot of work is accomplished and sand is redistributed.

On a developed beach we have a somewhat different situation because the shoreline is stabilized. Here the low seawalls can reflect most of the impact of the waves, increasing the turbulence, and a lot of that sand is eroded then; we end up losing intertidal sand volume. But that sand is not lost from the system. When we look at the spit ends or other locations along the beach -- one of the best locations to look at this is Goose Rocks -- we see significant accumulations of sand occurring elsewhere along a particular stretch of beach. Of course there is always the situation where the slightly higher water and storm energy will be absorbed by the seawall; we can anticipate more destruction in those areas.

Higgins Beach is another system where we've documented significant loss of intertidal sand volume because of the stabilization of the shoreline. You can see, even in this aerial photograph, the accumulation of this sand elsewhere within the system. It's not necessarily being lost offshore, and there is not much sand transfer from one system to the another. We're dealing with discrete units.

To show you this in terms of historical shoreline change, you can see that the areal extent here is growing due to loss of sand from this part of the system because of the stabilization of the shoreline.

In conclusion, we can see that there is significant variability going on in both the short-term and the long-term scale in which large volumes of sand are moving around within Maine's systems. For natural systems we can expect to see significant change. The beaches are responding in a very general way to this and maintaining their position relative to average sea level. There is going to be little or no impact on the natural beach systems that we'll be able to detect readily from that 15 centimeter increase in tidal range. Thank you.

MS. LeBLANC: The next speaker is going to be Dr. James Houston, Chief of the Research Division at WES, and his topics is going to be Hydrodynamic Modeling of the Bay of Fundy.

I want to remind the speaker again to watch that box over there with the lights, please.

HYDRODYNAMIC MODELING OF THE BAY OF FUNDY

DR. HOUSTON: I'm Jim Houston from the Coastal Engineering Research Center, U.S. Army Engineers Waterways Experiment Station.

I am going to be discussing hydrodynamic modeling of the Bay of Fundy. I believe most people in the room attended Dr. Greenberg's presentation yesterday. A few people probably did not. I am going to briefly review some of his major results and discuss the reasons for the controversy. Then I'll be describing some possible future hydrodynamic modeling in the United States.

To get you oriented, I will be discussing the Gulf of Maine/Bay of Fundy system. Tidal barriers would be up here in the upper Bay of Fundy. On the scale of this map they would be very tiny barriers.

A large number of barriers have been considered in the past. The largest barrier I think currently being considered is the Economy Barrier, which is a fairly small barrier compared with some of the previous barriers considered, such as the Blomidon Barrier.

I'm going to briefly discuss some of Greenberg's results for the Blomidon Barrier, because it's a much larger barrier than the Economy Barrier. I think these calculations stirred the original controversy. I'll briefly mention these calculations and then concentrate on the Economy Barrier case which is currently the largest case being considered.

Now, according to the original calculations by Greenberg presented in his 1976 report, the Blomidon Barrier would impact tidal amplitudes as shown on this slide. These are tidal amplitudes. Tidal ranges are twice these numbers. So at Boston we're talking about an impact in tidal range of 90 centimeters, which would be about 3 feet. The percentage impact increases as you move away from the barrier itself, becoming a maximum down in the area of Boston where there is a 33 percent impact.

These calculations stirred some controversy, as you might guess. A 3-foot impact on tidal range is extremely significant. A 33 percent impact in tidal range is quite dramatic. I think these calculation go against one's intuitive feelings of what should happen. Most people would assume that because these are small scale barriers and Boston is a considerable distance from the upper Bay of Fundy that intuitively you'd expect probably a negligible impact. In addition, one would probably expect the impact would decrease as you moved away from the barrier itself, whereas as shown here the percentage impact increases.

Dr. Greenberg yesterday described some of the reasons why his calculations, although not intuitive, are in his opinion correct. Basically what he's saying is if we assume the white line on this slide is the resonance response of the Gulf of Maine/Bay of Fundy system, he's saying it has a resonance peak at about 13 hours. The M2 tide has a period of about 12.42 hours.

Now, if you chop off a piece of the upper Bay of Fundy, even a fairly small piece, the net effect would be to shift this white curve to the left which would mean the resonance peak would shift closer to the period of the M2 tide. Because it's a fairly sharp resonant system, even a small decrease in the period

of the system will cause an increase in resonant response.

Whether or not this really is the resonant response of the system I think is debatable. There have been a number of investigations with various conclusions. Some studies have indicated the period of system is less than the M2 tide, in which case Greenberg's calculations would be hard to explain. I think though the more recent studies have generally indicated the period is around 13 hours and longer than the M2 tide.

A couple of years ago the Coastal Engineering Research Center was asked to review Greenberg's original 1976 report. At that time we had a significant number of criticisms of the original study. Since then Greenberg has performed other studies. He has an improved model and has made a number of new calculations. Many of the improvements to the model address criticisms we had initially. New calculations have changed the results fairly significantly. As far as I know there are no new calculations for the Blomidon scheme but there are new calculations for the Economy Barrier scheme.

The original calculations indicated for the Economy Barrier scheme at Boston there would be a 6 percent increase in tidal range. This is increased by a factor of two thirds, up to a 10 percent increase in the new calculations. I presume at Blomidon you'd have similar increase, maybe not by this magnitude, but it would be a good deal larger than 3 feet.

So as Dr. Greenberg used more accurate schemes and better boundary conditions, his results changed fairly significantly but they actually increased, which was not generally expected. I think a lot of people intuitively thought if many of the criticisms were answered, Greenberg's original calculations would prove to be too large. But in fact the tidal ranges increase fairly significantly in his new calculations.

So now the Economy Barrier scheme would increase the tidal range in Boston by about 27.8 centimeters or about a foot. This is the foot Greenberg was talking about yesterday.

It's important to realize we don't have an issue here of the United States versus Canada, where Canada is doing something for its benefit that would harm the U.S. The tidal barriers the Canadians are considering would also benefit the United States significantly if built. Most of the power would be used in the U.S. It would displace burning of foreign fuel oil. Burning of fuel oil, of course, has environmental impacts. Other methods to generate electric power, such as burning of coal, produce serious environmental impacts such as acid rain. I don't think nuclear power has been a popular idea in the New England area. So the scheme has a great appeal, I think, in this country. We are talking about a renewable energy source that would be nonpolluting. In this country there would be significant environmental gains, but also the possibility for significant environmental impacts. So I think we've reached the point now where we're trying to balance potential impacts with beneficial gains.

We've reached the point where now we really need to know quantitatively what the impacts are going to be. What are going to be the benefits? What are going to be adverse impacts? We need to weigh the benefits and impacts so policymakers can then decide whether or not we should go forward with the plan.

In the last year there have been a number of people calling for the United States to perform its own studies. Most of these studies would be environmental studies to look at environmental impacts, beach erosion and so forth. In addition there have been calls by people to perform new hydrodynamic calculations. These calls have come not only from this country. A recent quote from the Nova Scotia Tidal Power Corporation seems to indicate the Canadians are indicating new numerical hydrodynamic calculations are needed. Initially these calculations would be to essentially deny or confirm Greenberg's results. Later they would be used to make detailed calculations that could be used for environmental studies.

I am not indicating the Greenberg results are going to be false. I think there is an excellent chance his calculations are correct. The problem today is that you're dealing with complex models where a model can have tens of thousands of lines of code. People who deal with the numerical models know there is always a chance of coding errors and so forth. It's very difficult to know whether or not a model is correct, has no errors, and has been applied properly.

In the Corps of Engineers, what we've been talking about doing is applying an existing but separate numerical model to perform similar calculations to the Greenberg calculations. But we would be using very well tested models. In this country there are a large number of numerical models that are very similar to the Greenberg model, some of which are very well tested models. And what we'd be doing is applying such a model. The Waterways Experiment Station Implicit Flooding Model or the WIFM model is a very well-known and tested model that has been used for tidal hydrodynamics, storm surge, and tsunami propagation studies. The model solves the same type of equations that Greenberg solves, nonlinear long wave equations. WIFM uses an alternating direction implicit or ADI scheme which is a very efficient computational scheme. In addition, it uses a variable spaced grid network. A variable spaced grid network is used in real space and a uniform grid in computational space, with a coordinate transformation between the two.

If you remember yesterday in some of Greenberg's slides where he was showing the grid he used, part of his grid had a very fine scale and other parts of his grid were fairly coarse because he needs detail in certain areas of interest.

What Greenberg uses is an imbedded grid concept where the line between the coarse grid and the fine grid uses an interpolation type routine. Our general experience has been that in this type of transition, you get numerical reflections. In a system which is near resonance, we believe this could cause spurious answers. If you have a coordinate transformation that is done properly, you avoid that type of problem.

In addition, in more recent years, we've been going to what's called boundary fitted coordinates where the grid is not only variable but curvilinear. Using this approach, one can follow the shapes of very complex coastlines and resolve fine scale features of the problem.

As I've said this type model, and there are a number of other models in the United States, have been used very extensively. WIFM model has been widely used. The slide shows 20

representative tidal circulation applications throughout the United States. The model here has undergone peer review, been in front of citizen groups, in court cases, and so forth.

WIFM has been used for storm surge calculations. Many of these calculations are used in designing flood protection works, such as the height of levies and so forth; where accurate storm surge calculations are very important because you're not just talking about loss of property but possible loss of human life.

WIFM has been used for tsunamis; which are waves generated by earthquakes. This particular model was used by the Federal Emergency Management Agency to define flood levels of tsunamis in the United States.

To show you some representative cases, this slide shows an application at Great Egg Inlet, New Jersey, just showing part of the grid concentrated around the inlet itself. The light blue areas are marsh areas that during this particular phase of the tide are flooded. What we're typically looking at are impacts of structures such as jetties on tidal circulation, tidal prism, and so forth.

WIFM has been used in storm surge applications. This slide shows Galveston Bay, Texas, where we simulated Hurricane Carla, major hurricane. The yellow areas are land areas. White dots are areas that are normally land which are now flooded during this particular phase of the storm surge. Different colors represent different surge levels. Light blue, 3 to 6 feet. This is 6 to 9 feet and this color, 9 to 12 feet. There's a darker rose color which is 12 to 15 feet and another representing levels greater than 15 feet on later slides. The winds are blowing northwest, piling up the water in this area.

During a later phase of the tide, you get a 12 to 15 foot surge here and all of Galveston Island is under water, except for the City of Galveston itself, which is protected by a seawall. Then as the winds rotate, blowing due north now, flooding 12 to 15 feet occurs up near the Houston area. Part of Galveston Island is coming up above the water.

This slide shows comparisons between the numerical model calculations and tide gauge recordings of this surge. These are open coast tide gauge recordings. What we typically do in a surge application is to calibrate the model, using tidal information; that is, we would go out and measure tidal information, calibrate the model, fix all parameters, and then simulate historical events. Comparisons would then be made with tide gauge recordings and high water marks. For example, in this case we make comparisons with 26 high water marks.

One question: If we perform new calculations similar to Greenberg's calculations to confirm or deny his results, how useful is that type of information? I'm going to quote Greenberg. "It all depends on your perspective." I think if we perform calculations and we obtain the same results, that would basically confirm his calculations at least in a 2-dimensional, vertically integrated sense. And I'll discuss that a little further in a minute.

If there were differences, then I think he's right, you're going to have to start scratching your head, and what you would then probably do would be to compare the models by turning

terms on and off. Typically if there are going to be differences, if there are errors somewhere in the codes, it's going to be in certain sections of the code. You can turn off various terms, advective terms, for example, run models against the same situations and assure the boundary conditions are modeled exactly the same. I think by such a mechanism, you can track the differences, and the reasons for the differences. And then there are various conclusions that come from that.

There certainly is the possiblity, I'm not saying that it would be a large possibility, but there would be the possibility that an error would be found in Greenberg's calculations. It could be you would find there would be no significant impact on tidal heights outside the Bay of Fundy. If Greenberg's model was corrected and this model gave the same results, indicating no impact, then it would be a false alarm type situation. And we might stop all hydrodynamic calculations at that point. And that's certainly a possibility, maybe not a strong one.

More likely you'll find out that there is an impact on the tidal circulation or the tidal levels. I think then you have to go beyond that point and look at 3-dimensional numerical modeling. There have been a number of people such as Professor Brooks at Texas A & M University, that have made statements in the last year. I think a lot of people believe 3-dimensional effects -- that is, vertical variations in the water column -- may be important in determining the resonant responses in the system. Even if they don't influence the resonant responses to the system that significantly, there may be environmental impacts that depend on 3-dimensional representations. And so if you're going to make detailed environmental assessments you need to know in detail what those 3-dimensional effects are.

There are various 3-dimensional models that one could look at. One possible candidate would be the Coastal, Estuarine and Lake Circulation 3-D model, or the CELC3D model, which is a 3-dimensional model, not a vertically integrated model. This particular model is a fairly well tested model. There are others that are out there. And the reason you're interested in a 3-dimensional model, the reason this model was developed, is that many of the processes of interest are inherently 3-dimensional in nature. So for example, in a case where you have wind blowing across the system, it's well known that surface layers could be moving one direction, the bottom layers in a completely different direction.

In the Bay of Fundy you have important mixing processes that are occurring that are inherently 3-dimensional in nature.

This particular model uses the same type of horizontal grid that the WIFM model uses, and then a stretched coordinate grid in the vertical. It was originally developed for calculations in the Great Lakes where you have temperature stratification and complex flows in lakes such as Lake Erie; later applied to many coastal areas such as the Mississippi Sound and the Gulf of Mexico, also applied to other areas, such as Humbolt Bay in California.

To conclude this discussion with a quote, again from Professor Brooks from Texas A & M University and this is one I

think we'd all agree with, "Obviously it's to the best interest of both countries to understand some of the consequences of the Fundy dams before they are built or before they are not built." We don't want to be killing the dams unless we are sure of the calculations, sure that there really will be a significant impact. So it works both ways. We certainly don't want to be building the dams and then have significant environmental consequences that we did not anticipate that would be harmful. On the other hand, we don't want to kill something that could have significant benefits both to Canada and to the United States unless we're quite sure of the results. And I think in order to do that we're going to need the United States to look at things from its own end. There will be hydrodynamic calculations, but also I think many environmental studies, coastal engineering type studies, and beach erosion studies would be done to look at the possible impacts of the project. That completes my discussion.

MS. LeBLANC: The final speaker for this part of the session is going to be Mr. David Keeley from the Maine State Planning Office and his topic is going to be Impacts from the State of Maine Perspective.

IMPACTS FROM THE STATE OF MAINE PERSPECTIVE

MR. KEELEY: Good morning. My dubious task this morning is to try and provide a state perspective on the Fundy project, and perhaps more importantly to try and explain what the state views as necessary to further our understanding of the consequences of the project. I think as a number of us have pointed out this morning, tidal power certainly is a clean, safe, reliable, inflation-proof source of energy that can play an important role in New England's energy mix. At the same time the consequence of tidal power development must be acceptable. And it's the acceptability issue that brings us here today, and primarily is based on the type and magnitude of the projects on the shore and nearshore environment.

To help set the context for the state's view on tidal power, I'd like to speak briefly about the state's initiatives concerning tidal power. As many of you know, the state with the assistance of the Army Corps, has examined the feasibility or desirability of harnessing the tides along Maine's coast. Recently the State Planning Office and Office of Energy Resources completed a preliminary evaluation of Maine's tidal power resource. This study which was completed earlier this year is entitled A Tidal Power Inventory of the Maine Coast.

The project involved a preliminary inventory of the Maine coast from Kittery to Calais to locate potential tidal power sites. At the outset we suspected, as most of us would assume, that the most favorable sites would be in eastern Maine where the tidal range is the greatest, and where cultural conflicts would be limited. We identified nearly 250 sites and quickly reduced the number of realistic sites to fewer than 50. We then applied some more stringent physical and economic parameters and concluded, as no surprise to anyone, that Cobscook Bay in eastern Maine contained five tidal power alternatives ranging in size from 160 to 260 megawatts. The sites are characterized by an 18 foot tidal range and a basin there in excess of 30 square miles at high

tide. It's important to note as well that any development of one of these options would preclude the other four because the areas overlap considerably.

In addition, there were five smaller scale alternatives that exist in the bay with a total of 87 megawatts. These sites involve smaller bays in Cobscook Bay and consequently the entire tidal power potential of Cobscook Bay is approximately 350 megawatts. Outside of the bay there are only seven potential sites with installed capacities in excess of 10 megawatts, and they go down from there.

In summary, as I say to help put this Fundy project in a proper perspective, the entire tidal power potential of the Maine coast is less than 450 megawatts, considerably less than what the Fundy project would produce.

With that context, I would like to move on to what we feel are some important information needs that should be pursued in the future. These are not in any particular order. The first is that there is a need to clarify the existing regulatory procedures in the United States to insure that the impacts of the project can be, in our view, fully evaluated. At this time the United States has very little regulatory control over the projects and its anticipated impacts. Some discussion in the past has focused on the need for the project to be subject to the NEPA process. This would allow a complete U.S. examination of the project and would ease many concerns of people in the United States that the project is going to occur over strong U.S. opposition.

Second, there is a need to identify the role of the individual public utility commissions in allowing utilities to participate in the project and to determine what information requirements they have now. This issue has been largely addressed in the past, and as we approach the detail gathering phase, it would be desirable to know what information the public utility commissions will require to review individual utility involvement in the projects.

Third, the New England states need to jointly develop energy forecasts and determine likely sources to meet those forecasts. This forecast would set the tidal power project in the proper context since as we've noted already, roughly 90 percent of the power is projected to be sold to New England and New York utilities. In addition, New England Power Pool and the Power Authority of the State of New York should indicate what their power needs will be and possible sources of meeting those needs.

Fourth, the subject of tidal power development in the Bay of Fundy needs to be placed in a international forum to encourage a thorough discussion of the project. A number of us have spent many hours discussing this, including the New England governors and Eastern Canadian premiers. An impartial, bilateral institution such as the International Joint Commission charged to thoroughly evaluate the project would help both countries considerably in their decision-making processes.

Fifth, we must improve coordination of the gathering and dissemination of data pertinent to the Gulf of Maine and Bay of Fundy region. As has been discussed in the past, the Fundy Environmental Studies Committee is a good example of an informal

coordination mechanism which the United States should embrace.

In addition we should take advantage of the opportunity offered by this project to network our research efforts in the Gulf of Maine/Bay of Fundy area. We also support the involvement of the New England governors and Eastern Canadian premiers in disseminating information to state agencies, the research community and other people interested in the project. Related to this dissemination of information is the Anapolis project which recently went on line, and information there generated on such topics on fish mortality, turbine operation, generating periods and the like should be widely disseminated so that all of us understand what's going on in Anapolis.

Sixth, we need a carefully designed, well documented, credible verification of the model prepared by David Greenberg. All of the speculation to date on the potential impacts of the project on Maine's environment and it's coastal area are based on this computer model, and it's only prudent that a thorough verification exercise be performed. There are a number of methods that can be employed to verify the model. The New England states are interested in beginning this process. We encourage the Army Corps, NOAA, academia, research community and anyone else that's interested to initiate some sort of coordinated verification process. I think the sentiment is that until such time as a reputable verification of the model is performed, that the examination of the project's potential environmental impacts will not progress greatly.

Finally, upon verification of the model, government leaders, the research community and other people interested in the project should develop a list of research priorities to address the potential environmental and socioeconomic impacts. This list really addresses the last comments I had that it could be used to solicit and direct funding to the highest priority research needs. The list could be used by state and federal agencies, private organizations to insure that, one, all the issues are addressed, and two, that that they are examined in a comprehensive manner.

In summary, we need to initiate a formal, impartial, bilateral effort to examine the tidal power project. We need to verify the accuracy of the model. We need to obtain a good grasp on the anticipated impacts and implement a long-term research effort to address those impacts, and finally, we need need to better coordinate and disseminate information pertaining to the project. Thank you.

MS. LeBLANC: We're going to take a 15-minute break. I believe it's set up in the hallway, and then we're going to come back and the three speakers are going to sit up front and we're going to have questions and answers.

(A short recess was taken.)

MS. LeBLANC: We're going to get started now. Tom wanted me to mention that the poster session is still set up upstairs in the Scooner Room, and it will be there I guess until some time this afternoon. And there are handouts if anybody hasn't seen it yet.

We're going to start the discussion on the Bay of Fundy and we added two extra people up here, Dr. Greenberg and Peter Larson are up here. So you can ask any questions, and I

would like to ask that when you ask the questions that you go to the microphones please. So are there any questions?

MR. PEARCE: My name is Bryan Pearce. I'm from the University of Maine, and I'd just sort of like to make a statement. Oh, for I guess about six months now I have had a proposal in the mill, shall we say, together with Wendall Brown who is at the University of New Hampshire and in consort with Dave Brooks of Texas A & M, to study the Bay of Fundy tidal modeling problem, and fortunately it has been funded. And so we'll have myself and a couple of graduate students thrashing away at this problem. The University of Maine part will be for the modeling.

Wendall Brown is going to be taking perhaps some data designed to help this problem and also to look at the general circulation in the Gulf of Maine. He'll be taking some time series pressure measurements, and Dave Brooks, and we've been working with him for two years now, and he's going to continue on his program with synoptic density measurements. That quote from Dave Brooks, by the way, that Jim Houston showed is from my proposal. He admits it. We also hope to work with Dave Greenberg, although the question is how much should we work with him since we're supposed to have a different and independent appraisal.

And finally, just to throw off the discussion perhaps, the panel could talk about the ocean boundary problem.

MS. LeBLANC: Thank you. Peter Larson would like to make a statement.

DR. LARSEN: There is just one thing I would like to point out, and I know this is a very intelligent and enlightened audience, but sometimes people fall asleep before the ends of talks and perhaps lose the significance of some things. It's happened once or twice before.

Yesterday afternoon Dave Greenberg put up a very nice slide comparing the effect on instantaneous sea level of various things -- wind, waves, seasonal changes, tidal waves, storm surges whatever -- and made that 15 centimeter increase in the high tide line look pretty insignificant compared to them. But then he did close by saying about if you're standing neck deep in water, that 15 centimeter may become very significant.

This morning Ken Fink spent a lot of time doing long term averages, long term patterns in sea level variability and then quite correctly concluded that sand beaches have responded to this, so 15 centimeters additional on an unstabilized beach might not be that critical in that environment. Both of these statements though concluded correctly might leave someone with the impression that since 15 centimeters is small compared to these other variabilities, we don't have to worry about it. Some well known scientists have actually said that.

It's important to remember that the proposed changes in the tidal regime are just that, changes in the tidal levels. You'll now have an increase in this case in the tidal range, and these other sorts of variabilities will happen on top of that, okay. These other sorts of variability are independent of the astronomical tides, and therefore the comparison of the height of the storm wave with the height of the tidal change is not a valid comparison.

MS. LeBLANC: Thank you.

DR. KELLEY: My name is Joe Kelley, and I'm a marine geologist with the Maine Geological Survey. A couple of comments and then a general question. Comments regarding some of Ken Fink's presentation. I was always taught that the reason there were different wave heights experienced on the East Coast, the Gulf Coast and the West Coast were due to continental shelf widths and not storm, particular kinds of storms we receive.

In addiion, storm tide height increasing from, well, southern Maine to Portland, central Maine is at least partly controlled by the doubling of the tidal range from extreme southern Maine to the Portland area. Washover not being an important process in Maine, certainly it isn't very important on some of the very conspicuous and developed beaches in southern Maine, but I believe it is an important process on some of the more smaller beaches, the fairly numerous beaches in the less developed northern part of the state. And this afternoon I'll show some evidence for complete overwashing and drowning of beaches within historical as well as geological timeframes in the Gulf of Maine. I won't comment on the date on the peat in a horizontal translation of the beach other than to note that there are certainly contamination problems present in dating materials exposed in the surf zone.

A question not related to that would be addressed to David Keeley. I wonder in the Fundy tidal power study that was funded by his office, it was noted that the increase in the range would drown a lot of private property, and people would lose a lot of their property. Of course, in the State of Maine people own to mean low tide. And in fact people's property would be extended not decreased by the increase in the range. I wonder if the State Planning Office has made any evaluation of the loss of revenues to the Bureau of Public Lands which derives income from renting subtidal properties to people on the basis of this proposed effect.

MR. KEELEY: Well, Joe and I talked a little bit about this last night, and no, we haven't looked at that yet.

MS. LeBLANC: Are there any more questions? We have a response first.

DR. FINK: Just briefly, Joe, I wasn't attacking the cause of the wave heights along the North Atlantic coast. I was simply commenting on the fact that that's what the data say. I wasn't implying that the storms were responsible for that. Oh, and the peat day, by the way, is the result of Liddy Humes (phonetic) thesis down at the University of Delaware. There's not been very much made of that. It's the only indication we have of any sort of horizontal offset. There needs to be a lot more work done in that area, as you know.

DR. BELKNAP: Dan Belnap, University of Maine. I'd like to applaud Peter Larsen's last statement. I think that's very important. I understand that the chin versus nose argument about the 15 centimeters.

I'd like to comment on some of the things Ken Fink said earlier. He was talking about this 15 centimeter rise not being important in terms of variability. I think we do have to consider that it's going to increase the frequency of flooding by a factor of perhaps 3 on undeveloped beaches that might not be important in a human sense, but certainly on the developed beaches

the seawalls are going to be overtopped three times as frequently. This is very significant.

Also Ken didn't mention the range increase or the increase of currents, also the fact that the lower tide line is going to affect the distribution of sediment in the system. Certainly it's a leaky system in some ways, and some of the sand is going to leak to the below wave base part of the profile in the broom rule. These things have to be considered. And finally I'd just like to mention that sandy beaches are only one percent of the coast of Maine. There are many more significant areas.

MS. LeBLANC: Thank you. Are there any more questions or comments? Ken Fink would like to make a comment.

DR. FINK: Dan is absolutely right. I was not trying to say that the 15 centimeter increase was insignificant. I was simply saying that beaches have already responded to that degree of change, and we shouldn't expect that the beaches to be unable to respond to that increase in the 15 centimeter range. That's all I was saying. I'm not saying it's insignificant.

In terms of wave overwash, clearly you have a greater possibility of that occurring. As I say, that's only going to help the beaches maintain their supertidal elevation relative to changes in sea level that will occur. There was one other comment.

DR. KELLEY: Tidal range, low tide and current.

DR. FINK: Oh, yes, that sort of thing, the currents, and again as as I say, most of the sand is still contained within that system. The amount of sand we're actually losing from each system we don't really have any idea at all. The rates at this present time suggest that, particularly with regard to recovery from storm events, we see that this occurs reasonably quickly, suggesting that there is an ample supply of sand in the inner tidal and subtidal area to resupply the sand to the beach and build its new elevation. And this seems to occur annually and with relative ease. I want to emphasize that in terms of increase in currents, I'm sure Dan is talking to some extent about the tidal inlets. Again I want to emphasize that my comments were not even including tidal inlet areas. I think that's where we can expect to see some significant changes taking place. I know that Duncan Fitzgerald, he's been working with us up here in Maine, will have a lot to say about that, maybe at least two times. So that I think we'll have a completely different picture in terms of the tidal inlet store.

MR. BAER: I'm Ledolph Baer from NOAA. Since this is a Corps of Engineers meeting, it gives me a chance to ask a question that I've been trying to ask privately for a long time unsuccessfully. Jim, you showed a number of models there and half this audience is probably not hydrodynamicists, perhaps more. One of the things that has bothered a number of us is that the Corps of Engineers typically keeps its models fairly private and only puts them in reports as opposed to getting them out for peer review and having them critiqued by the scientific community. . So that the scientific community really doesn't know what the Corps has, doesn't know whether they are good or bad, and until the Corps is willing to spend the time to publish its work completely and put its data up for criticism, I think that the scientific community is not going to completely accept such

things.

Then, a second comment, you listed a lot of applications of the model that you were proposing to use. And as far as I know, all of those are very inshore, so that none of them are offshore covering deep water such as you have in the Gulf of Maine here, and what makes you so sure that models that have been used almost exclusively inshore are completely acceptable offshore.

DR. HOUSTON: I think all the models I've discussed have been published extensively. They have undergone peer review. There have been a large of number of publications. Many of our applications have been in shallow water areas. However, many of the applications have not been. For example, the tsunamis applications involved the propagation of tsunamis across the Pacific Ocean, 10 to 15,000 foot water depths.

MR. BEAR: You're using the exact same model?

DR. HOUSTON: Very similar models, yes. But I think we can provide you with a list of publications. All the projects that I showed you, there are publications on the particular application and there are publications describing the models and the theory behind the models and calibrations and verifications.

MR. BAER:. It just seems to be sort of a Corps policy not to publish in the general reference literature.

DR. HOUSTON: I don't think that's true. And your statement that the models are not available I think is also not true. All the models in the Corps of Engineers are available to the public.

MR. BAER:: I didn't say weren't available. I just said they haven't been peer reviewed outside of the Corps.

DR. HOUSTON: And are being used for example by private---

MR. BEAR: I said haven't been peer reviewed.

DR. HOUSTON: They have been presented in general publications, conferences.

MR. BAER:: I must be missing them.

MR. BUTLER: I'm Lee Butler, Coastal Engineering Research Center. I was the author of WIFM when it was presented. I guess it's been presented in three coastal conferences. The one in Hawaii, the one in Hamburg, the one in Houston, one in South Africa. There's been -- I'm trying to remember, there's a number of publication. We have many WES reports. There's a WES report out on the 3-dimensional model available. I'd be glad to take a list of requests.

But I would say that basically all of the models that we have, as Jim said, are available to the public. We're actually make a push right now to develop a system, coastal modeling system that will attempt to consolidate a number of the different models that we use under the guise of a single model documentation for use by the field, the Corps, as well whoever else needs the system. And that's due for release sometime next year. We intend to have a workshop at the Corps of Engineers research center. That's planned for next spring for the use of the system. Our work is available.

MS. LeBLANC: Are there any more questions?

MS. SPILLER: Judy Spiller, University of New Hampshire. I've a question for Dr. Houston. I wonder, is the

availability of observational data a limitation in applying some of the models that you've discussed? And maybe this could be directed toward Bryan Pearce also. And I ask that question in light of two factors, one is a truism that models ultimately are only as good as the data that you feed into them. And the other point is something that Ken Fink raised, which is that it seems to understand the responsive beaches along the coast of Maine to these sort of changes, you need to conduct a lot of site specific studies.

DR. HOUSTON: I'd say undoubtedly if you want to make detailed predictions that you have high confidence in, there undoubtedly will have to be a good deal more prototype data collected both for the hydrodynamic modeling, I think for environmental modeling, a look at beach responses and so forth. I think that probably the major cost of future studies would be collecting prototype data. And without it I think a lot of the predictions would be suspect.

I think Bryan Pearce mentioned one problem, the open boundary problem. That would be a problem for hydrodynamics. Certainly environmental studies you need significant base lines. I think in order to make detailed calculations and really understand the impact of the Fundy dam, it will take significant efforts in collecting prototype data. So I would agree with you.

MS. SPILLER: I shouldn't have sat down so quickly, but can you give any sort of estimate on the time that would be involved in collecting that kind of information? I've gotten the impression in some of these discussions that the Corps models could be applied fairly quickly. But now it sounds as though a multi-year research project needs to be launched to collect the data to apply the models.

DR. HOUSTON: Well, the two dimensional models I was talking about where you confirm or deny Greenberg's results, I think could be conducted immediately.

If you talk about 3-dimensional modeling, obviously you're going to need a significant effort. And I think that effort has been estimated by the New England Division and published in the Augusta, Maine proceedings of Congress. I can't estimate some of the times because a lot of these things I think would be environmental studies of which I would not be an expert. Hydrodynamic studies I think would probably require a good deal less time than most of the environmental studies actually, because a lot of environmental studies you need significant periods of time to pass to look at various phenomenon, whereas hydrodynamic modeling you can measure the variables relatively quickly.

Are there any environment list here who can give us an idea for environmental modeling what kind of timeframes you're talking about to obtain data?

MR. SPAULDING: My name is Malcom Spaulding from the University of Rhode Island and Applied Sciences Associates, Inc. We've been working on hydrodynamic modeling, complete transport modeling, ecosystems modeling, fisheries population modeling in the Georges Bank/Gulf of Maine region for about the last four years. Later on today I'll present, actually tonight, I will present some results of some simulations that we've done on the 2-dimensional vertically average circulation in the Georges

Bank/Gulf of Maine region looking at the tidal residual flows, and then in addition I will present some information we've been working on in terms of 3-dimensional circulation modeling looking at long-term residual flows, seasonal variations in circulation dynamics, mainly on a time scale of three months, and with density, winds, longshore fracture gradient and tidally induced flows. And we can see, take a look at some of these model results and compare them, see some of Dave's calculations and see the similarities and the difference between those two from a modeling approach that is entirely different from the one that Dave proposes is 3-dimensional, is time dependent, and has included some of the other forcing mechanisms.

MS. LeBLANC: Are there any more questions or comments?

DR. KELLEY: My name is Joe Kelley again, with the Maine Geological Survey. Just one last question. This might have been answered or it might even be obvious although physical oceanography has never been very obvious to me. I'd like to ask how quickly would the tides of the Gulf of Maine respond to the completion of the barrage? Would this be an instantaneous change in the tidal range or would there be a period of years during which the system reached an equilibration?

DR. GREENBERG: The changes would occur -- well, let's put it another way. If I start with a model that doesn't have the barriers in and then say, God put a barrier in overnight, it approaches a steady stage in about two to four days of simulation. God might not put the barrier in quite that quickly.

The construction time, depending on who you talk to, is somewhere between five to ten years, but the closure time, the critical closure time and I think I'll hand it over to Peter in a second, I think it's only in the order of less than a year to maybe a few months when you start to close it down enough that the whole bay/gulf system starts to feel it. And so it would only be a couple day after each step it starts to feel these little increments, but it would be a short time. I think Georges Bank made a quick, back-of-the-envelope estimate for Peter, and if he remembers the answer, I'll give it to him.

DR. LARSEN: I can comment on that in a secondhand sort of way. We put that question to a number of people because obviously certain systems, the time scale of response is different and something gradual over ten years might be imperceptible, something suddenly over a week could be quite disastrous. Georges Bank, the executive vice-president of the Fundy Tidal Power Corporation did some calculations, and I do have a graph of his results that I could show you. And I believe his results show that the major changes in tidal range would occur towards the mid to three quarters construction period over a period of two to three years. Hugh Toland of the -- he's at Taunton, United Kingdom. I forget the specific name of the institute he works at. He's the one doing the modeling on this 7 estuary barrage. He had a slightly different opinion and thought that you would reach threshold during the closure, and the tidal regime would change at a fairly rapid rate, a period of weeks probably.

DR. KELLEY: Just to follow that up. I wonder, you're a biologist, Peter, maybe you know, how quickly could plant communities zoned with respect to the tides adjust to this

change? Salt marshes or seaweeds along the rocky coast.

DR. LARSEN: Although I'm a biologist, when I get a question like that I specify that I'm a zoologist. I personally think that the critical thing in a marsh is how quickly the sediments can reach a new equilibrium. Most intertidal species are pretty plastic. If the environment is there, they will occupy it.

MR. PRAST: My name is Bill Prast of Atlantis, Incorporated. I'd like to ask the panel to comment on lead times which have been referred to with respect to plant community reactions and the behavior of the intertidal zone. The lead time on this project will, of course, depend on decisions by both Canadians and the Americans. At this point it would seem because it's a 4000 megawatt proposal and the process of digesting the 10,000 megawatt Ron Rivier (phonetic) project in Quebec has not yet been fully completed by either NEPOOL or Canadian electricity users that there may be quite some period of time before any financing decision and the rest are made.

I'm wondering if there are any critical areas of research which the panel might comment on which they feel would require the most amount of time for further study and which they would prioritize in the event that a commercial decision appeared imminent on the part of the Canadian authorities.

DR. GREENBERG: Critical times, I can't comment on but the sort of leads times that people are talking about, and I don't know whether anybody has mentioned it yet, if somebody said okay, let's go right now, the next thing that would happen would be the design phase of study which would have turnoff points if some of the preliminary feasibility calculations weren't right, and that is estimated to take from three to five years and many millions of dollars.

The time of construction, as I've already mentioned, is somewhere in the neighborhood of five to ten years. So we'd all be old people by the time we see tidal power even if somebody turns around and says we're going to do it tomorrow.

DR. LARSEN: I would like to say as an ecologist that usually, or it's obvious that it's economic and political considerations that drive any power project or any large construction project. And the environmental questions aren't given all the consideration that they deserve, some of us believe they deserve. This case is somewhat different in that you're talking about one of the basic force and functions of the Gulf of Maine, and you'll influence the processes of the Gulf of Maine, geological, biological, chemical processes.

The question came up before about base lines and times of the study. Well right now I think some, in certain areas the data exist at this time. So that some I think important questions could be answered. In other cases that is not the case. Indeed there are questions I'm sure that haven't even been anticipated yet and won't come up until we become involved. There is never enough time, but I think these more basic questions might take a period of some 3 to 5 years, others 5 to 7 years. It becomes obvious that that's a longer period of time than the precommitment study, the engineering studies. So you will not at that schedule have the environmental questions answered in time to have them as part of the decision making process.

I would really like to see this case handled in an ideal way where all these environmental questions are answered before the engineering phase starts. So that the results of the system studies can maybe be factored into the engineering decisions. There may be ways of changing location or operation of the dam to mitigate some of the perceived environmental impacts. So if the question is lead time, I would like to see environmental studies begun 5 or 7 years before the engineer start putting stuff down on blueprints, because once that stage is reached it's very difficult and have expensive to make modifications.

DR. FINK: I'd like to make another statement on that same question is that we're very fortunate in Maine in having had a lot of people at the university, other universities in New England working along the coast of Maine, so there is a fairly good data base that exist already. I think we owe Peter and Jerry Topinka a real debt of graditude for allowing with this opportunity over the last year or so to take a new look at the data base that we already have. It's been very stimulating, and just based on some of the conversations I've had with colleagues of mine over the last six months or so, it's plain to see that there is going to be a lot of new information from this, looking at our data in completely new way.

MS. LeBLANC: Are there any more questions?

MR. SHENG: My name is Peter Sheng from Aeronautical Research Associates, Princeton. I've a question with regard to the impact of the Bay of Fundy tidal power plant. As we know there are various spatial scales and this problem various from all these meters or tenths of meters right in the vicinity of the gates of the tidal power plant to hundreds of kilometers as the model predicts. And as the model predictions have indicated, the effect of the tidal power plant could reach hundreds of meters away, hundreds of miles away. But my basic question is unless one is absolutely sure that one can model the small scale problems absolutely correctly, accurately, how is one going to be able to make judgments on the predictions hundreds of miles away? And the main question is to Dr. Greenberg, the numerical grid that he used, the smallest grid is on the order of two kilometers which is much, much bigger than the gates at the tidal power plant. My question is how does he represent these kind of small scale hydraulic characteristics of the structures? Has there been any field study or laboratory study on these small scale problems?

DR. GREENBERG: The gates in the model are presented in a course way in that the actual grid size is about a mile 1.6 kilometers in the upper area. We looked at each grid cell and said how many sluice gates, how many turbines would be in that area when we take a flow Constance saying with what difference in elevation across the barrier, given the difference in elevation across the barrier which is a model parameter, what flow do you get through the barrier. And that sort of thing engineers I think are pretty competent to tell you how much water is going to you go through the barrier, and once you've got the flow across one side of a grid box, you've got your equation of continuity already satisfied. So it's a matter of taking these gross features and working it into the first order calculations of tide anyway.

The details of what's happening, the eddying around the turbines and sluice gates, that's fine tuning. I don't think

we're talking about big differences away from the barrier. As an example, if we shut the barrier completely, I think we're pretty good at modeling a solid wall. We still end up with changes as far away as Boston. At the same order of magnitude, they are slightly different because the friction effects are different and the actual flow up there does matter a little bit. But we still end up with the far field effects. So it's fine tuning to say we have to look at every turbine in the eddy between it and the next turbine in the sluice gates when what's opened and going which way.

Similar sort of thing, we ended up with have similar effects whether we looked at the ebb generation type turbines that I talked about yesterday or whether we tried something like putting the turbines generating into the reservoir, and uneconomic sort of proposition, or if we looked at generation in both directions, trying to manage the tides so that you're generate in both directions for 3 or 4 hours and then stopping, filling the other pool or draining stuff into the ocean, whichever way you're trying to go. We still end with the same sort of effects down in Boston and the far field. So the fine tuning around the barrier I don't think is going to be critical to the answer that we're getting along the Maine or New England coast or even the Bay of Fundy coast.

DR. BELKNAP: Dan Belnap, University of Maine. I'd like to ask a question of the panel that was raised in the Larsen and Topinka report. Engineering structures usually have an effective life time of 50 to a hundred years. And if we do have environmental consequences during the constructional phase, we're likely to have as severe consequences during the decommissioning stage or when the system is inoperative. Can we comment on that?

DR. LARSEN: I could comment on that, that paragraph was put in as a last minute after thought by someone other than myself. We have all said just the fact that everything comes to an end. So some day presumably someone will have to face that problem. Again, in talks with Georges Bank about the actual life span rather than the projected one used for economic reasons, what he expect it to be, and he says the experience with turbines of this type and this sort of system that unless impoundment fills in, there is no reason to believe that we have to worry about it. That is, it will have almost an infinite life time, and I guess the models now show that the impoundment is not likely to fill in. So I'm not spending a lot of time worrying about the impacts of the closure of the dam right now.

MS. LeBLANC: We have time for one more question.

(No response.)

MS. LeBLANC: Would anybody on the panel like to make a comment?

(No response.)

MS. LeBLANC: All right. We're going to turn it over to the next session, and the next monitor will be Jim Doucakis.

MR. DOUCAKIS: The next topic is Coastal Inlets, and the first speaker will be Dr. Duncan Fitzgerald, a professor at Boston University, and his title is Tidal Inlets Along the New England Coast.

TIDAL INLETS ALONG THE NEW ENGLAND COAST

INTRODUCTION

DR. FITZGERALD: There are two major objectives in my presentation today. I want to familiarize you with the settings of tidal inlets along the New England coast and discuss a little bit about what we have learned about tidal inlets during our eight years of study. The second subject I will discuss are the effects that the Bay of Fundy project will have on tidal inlets in Maine and what their effects will be on adjacent beaches. The situation is a complex response to increasing tidal range, causing an increase in tidal prism.

LOCATION OF INLETS

First of all, I want to explain the uniqueness of tidal inlet systems in New England, then I will go on to discuss where tidal inlets are located along the New England coast, their morphological variability, and finally the processes affecting sediment transport patterns.

The first point I'd like to make is that tidal inlet systems in New England are very different from their southern counterparts, including these located along the rest of the Eastern and Gulf Coasts. This is due primarily to the effects of glaciation. The size, number and location of tidal inlets in New England is related to glacial erosion and depositional processes and the types of coastal settings that glacial processes have formed. South of New England, we find that tidal inlets exist along barrier island coasts that extend almost uninterruptedly from Long Island all the way to the Yucatan peninsula. An xample of this type of setting would be Fire Island and the downdrift overlap Fire Island Inlet along the Long Island coast.

Similar morphology is found along the northern New Jersey coast. Here, we have long linear barrier islands and few tidal inlets. Along the southern New Jersey coast, there are shorter barrier islands and many more tidal inlets. The reason for this is due to an increase in tidal range. As we increase the tidal range, we increase the tidal prism. Thus, we have more water going into and out of the backbarrier system. Consequently, we need more holes in the barrier (i.e. more tidal inlets) to let the greater volume of water into and out of the lagoon.

Tidal inlets along the Outer Banks of North Carolina provide an access for water from the Atlantic Ocean to enter the large bays of Albemarle Sound and Pamlico Sound. Along the South Carolina coast, tidal inlets separate numerous beachridge barrier islands.

Along the Georgia coast, there is an increase in tidal range and in the arca of backbarrier environment. This produces larger tidal prisms and larger-sized tidal inlets.

The New England Barrier Island-tidal inlet systems are quite different from those previously discussed. In New England tidal inlets are not associated with long linear barrier island systems, rather they are found next to barrier spits. In Northern New England, barrier spits and barrier beaches occur in two general locations. First, there are those associated with major estuaries like the Popham Beach system at the mouth of the Kennebec. These barriers were formed from sands brought down the estuaries during deglaciation. The second type of setting where

we find tidal inlets and barrier spits occurs in large cuspate-shaped embayments. The sand that formed these barriers was probably driven onshore during the Holocene transgression by wave action.

We do have one exception to this general trend and that occurs along northern Massachusetts. From Boars Head to Cape Ann there exists a long linear barrier island system that is cut by several tidal inlets. These include Hampton Beach, Hampton River Inlet, Salisbury Beach, Merrimac River Inlet, Plum Island, Parker River Inlet, Crane Beach, Essex River Inlet, Coffin Beach and finally the Annisquam River Inlet. So we do have one barrier island-tidal inlet system, but by and large the rest of the New England coast is very different from the mid-Atlantic barrier island coast.

One feature that is common to most tidal inlets in New England is that they are structurally controlled. They are stabilized on one side by a bedrock headland and on the opposite side is a sandy spit. A cross section of the Inlet channel would show that the channel is much deeper along the side that abuts the bedrock. The structural control of the tidal inlets in New England (outside of Cape Cod) prevent their migration. The general setting of tidal inlets is consistent from Maine to Buzzards Bay.

One slightly different situation occurs at Parker River Inlet. At this site the bedrock is replaced by a large drumlin, which serves to anchor and stabilize the inlet. Again, the channel cross section is deeper along the downdrift side of the inlet.

Along the coast of Cape Cod the formation of inlets and the resulting morphology is slightly different when compared to Northern New England. After deglaciation the original coast of Cape Cod consisted of unconsolidated glacial sediments with numerous irregular bays. Tidal inlets were formed in this area by spit progradation across embayments. This has occurred on a large scale like Sandy Neck building in front of Barnstable Harbor on where Nauset spit has prograded across Pleasant Bay. The process also occurs on a much smaller scale in the Cape Cod region. For instance, in South Dennis, a small spit has formed at the mouth of Bass River Inlet.

One other location where tidal inlets occur along the Cape Cod shore is at the openings of north-southward trending ponds. These ponds were once valleys that were formed by melt water streams cutting into the outwash plain. The valleys were subsequently inundated by a rising sea level during deglaciation. The small size of the ponds and low tidal ranges of the region produce small tidal prisms, small inlet cross sectional areas and shallow channels. Consequently, many of these inlets are jettied and dredged on a regular basis.

INLET MORPHOLOGY

While the general setting of the inlets in New England is similar, their morphology exhibits a great deal of variation. The reason for this is a tremendous amount of variation in their size, backbarrier setting and their hydrographic regime. There are areas like Cape Cod where tidal inlets occur along unconsolidated sediment coasts. In contrast, there are areas in Maine and parts of New Hampshire and

Massachusetts where bedrock controls the size of the backbarrier and location of the inlet.

HYDROGRAPHIC REGIME

Hydrographic regime, which is a function of tidal range and wave height, also varies considerably along the New England coast. For example, areas in Nantucket Sound tidal ranges up to 60 centimeters, whereas in Eastport, Maine tidal ranges approach 6. The largest waves in New England break along the outer coast of Cape Cod where mean wave height are about 100 centimeters. Much lower wave energies (H - 40cm) occur in protected areas like Buzzards Bay and Nantucket Sound. Intermediate wave engergies (40cm - H - 100cm) occur along the North and South Shores of Boston and along the southern Maine coast. In terms of Hayes' (1979) classification the New England coastline encompasses wave dominated settings, mixed energy settings, and tide dominating settings.

BACKBARRIER SETTING

In New England backbarrier enviornments consist of marshes and tidal creeks, open water areas on a combination of the two. Herring River Inlet, which is located along Cape Cod Bay, is a good example of an inlet backed by marsh and tidal creeks. This area was formed by the inundation of a large kettle during rising sea level following deglaciation. A spit built southward across the drowned kettle. The original open bay was eventually filled with the formation of flood-tidal deltas and the deposition of fine-grained material. Spartina grasses gradually colonized the intertidal regions of the bay leading to the development of the present day morphology.

A slightly different backbarrier setting is found at Pamet River Inlet in Truro, Cape Cod.

Here the bay consists of half marsh and tidal flats and half open water. At Slocum River Inlet in Buzzards Bay, there is almost no marsh growth in the bay. The entire backbarrier consists of open water.

TIDAL DELTAS

Tidal deltas in New England maybe well developed or totally absent. Essex River inlet, which is located between Crane Beach and Coffin Beach, Massachusetts, is an example of an inlet with a well formed, symmetrical ebb-tidal delta. Scarboro River Inlet in Maine is another example. Both of these inlets also have well developed flood-tidal deltas.

Flood tidal deltas are horseshoe shaped deposits found behind tidal inlets. At some small-sized inlets in Maine, like Ogunquit River Inlet, there are multiple flood-tidal deltas. At Westport River inlet there is a poorly developed, mostly subtidal, ebb-tidal delta system and really no flood tidal delta system. The factors that seem to control the morphology of these inlet sand bodies are the size of the tidal inlets, their tidal range, and sediment supply.

HYDRAULICS AND SEDIMENT TRANSPORT PATTERNS

TIDAL CURRENT DOMINANCE

It is important when studying tide inlets to discern the dominant tidal currents in the channels. This helps in determining pathways of net sediment transport. The dominant tidal current is defined as the current having the maximum velocity. The maximum current velocity dictates the direction in which the

sand will be moved. This is because bed load sediment transport is related to the cube of the velocity or some higher power. Consequently slightly stronger current velocity in one direction or the other, clearly results in a dominant sediment transport system.

In a study of eight tidal inlets in Massachusetts and seven inlets in Maine, it is apparent that inlet hydraulics are controlled by tidal range, the size of the tidal inlet and the setting of backbarrier environment.

Small-sized tidal inlets (width - 100m) are dominated by flood tidal currents. At Ogunquit River inlet in southern Maine flood velocities are 10-20cm/sec stronger than the ebb currents. The stronger flood tidal currents of this particular inlet are related to the tidal duration differences. The ebb duration lasts 60-80 minutes longer than does the flood duration. And quite simply, if the water has a shorter interval to enter the inlet than to leave it, it has to move more quickly. The durations are, in turn, related to the size of the inlet. Halfway through the ebb cycle, the swash platform which borders the spit comes out of the water. This means that all the currents that are discharging out of the inlet are confined to the small main ebb channel. Therefore, before water can enter the inlet, the rising ocean tide must overcome the interia of the ebb tidal currents. This causes a steeping of the tidal wave and a shorter flood than ebb duration.

In larger tidal inlets with deeper channels, there is a freer exchange of water between the ocean and the bay. At these tidal inlets we have noted dominant ebb-tidal currents.

At Scarboro River inlet in Maine a plot of tidal range versus maximum current velocity for the flood and ebb cycles shows that for any given tidal range the ebb currents will dominate those of the flood currents. It also should be noted that this pattern increases with increasing tidal range.

SAND CIRCULATION

At smaller tidal inlets we have identified two sediment transport patterns. One consists of a sediment gyre that occurs between the swash platform and the main ebb channel. In this case, wave-generated currents and flood-tidal currents carry sand across the swash platform and deposit it into the main channel. Dominant ebb currents in the outer channel carry the sand in a net seaward direction and deposit it in the shallow nearshore. Wave action will then transport the sand back on shore to the swash platform, thus, completing the sediment gyre.

The other sediment pattern occurs when sand is transported around the spit and into the inlet throat. Dominant flood-tidal currents transport this sediment into the backbarrier environment. Geomorphic evidence of this process is the presence of multiple flood-tidal deltas and sand clogged channels far from the inlet mouth.

Along open ocean coasts, like Nauset Inlet on the outer Cape Cod, strong wave energy causes a continual net longshore movement of sediment toward the inlets. At these sites, inlet sediment bypassing is an active process. At Nauset Inlet sediment is being transported from north to south. Sand enters the inlet through the marginal flood channels and across the channel marginal linear bars into the main ebb channel. While

some of this sand is moved into the backbarrier, most of the sand is transported to the distal portion of the ebb tidal delta. Wave action is then responsible for forming large swash bars that migrate on shore. It is important to note that the sand is not continuously transported to the downdrift barrier, rather it is transported in packets. These packets are the individual bar systems. Consequently, the downdrift beaches that are being nourished by this sediment will respond to changes in sediment supply.

Along the highly indented coast of Maine, there occurs a large sediment gyre dominating the mouth of the Kennebec River Estuary. A clockwise circulation of sand at the western side of the estuary produces the landward migration of a 10-15km length sand bar that is 2-3m high. The height of the bars precludes their confusion with ridge and runnels which are much smaller.

CONCLUSIONS

In conclusion tidal inlets in New England are structurally controlled unlike their southern counterparts. New England tidal inlets exhibit a wide degree of variability due to wide range of physical settings, hydrographic regimes, different sediments supplies. The ebb or flood dominance of an inlet is a function of inlet size, tidal range and back barrier environment.

MR. DOUCAKIS: Thank you very much, Duncan. The next speaker is Mr. Curt Mason, and his topic is Characteristics and Stability of Tidal Inlets. Mr. Mason is Chief of the Field Research Facility at Duck, North Carolina.

CHARACTERISTICS AND STABILITY OF TIDAL INLETS

MR. MASON: First of all we're not dealing in this presentation with rocky headland areas or inlets controlled by fixed sides. We're dealing with tidal inlets on a sandy coast, such as Drum Inlet on North Carolina, consisting of a flood tidal delta in the bay and an ebb tidal delta in the ocean.

The importance of inlets relates to navigation, for one. The Corps spends millions of dollars each year dredging navigable inlets, which sometimes are not so navigable. In our area in North Carolina, three dredges of this type were brought in for a period of two months in order to maintain one tidal inlet. So we're talking about a lot of money being expended, and research is needed to improve the maintenance dredging procedures and the improvements at inlets.

Inlets are also important to biological interests by providing a pathway between nursery grounds in the bays and the ocean waters. And they are also important in flushing of interior bays, pollutants and so on. Finally, inlets allow storm surges to reach interior coastal areas, and so predicting the hydraulics of flow during these severe conditions is also important.

Let's talk for just a minute about inlet hydraulics, i.e. about flow generated by a difference in water level between the ocean and the bay. Idealistically, as shown in this slide, we have a sinusoidal ocean tide curve and a bay tide which responds in some manner to the flow of water through the inlet. In this case there is a reduction in tide range, and a lag in the high and low water times between the ocean and the bay tide. This

generates a difference in water level elevation which produces gravity flow, and the characteristics of this flow and the timing of it are what I want to talk about. Duncan mentioned the ebb versus the flood predominance. I'll look at some of the reasons for that occurring.

Consider first a bay which has a constant area. In a bay like this, the bay tide response will be somewhat along the lines of what I just showed you. However, we next consider a more realistically shaped bay, which has a bottom shape something like this, characterized by a series of channels which have islands between them, and these islands become overtopped at some tide stage. So as the water surface rises in the bay through these channels, the bay area increase somewhat as a function of the slope of the channel. At the point that the marsh islands are overtopped, there is a sudden increase in the bay area to a rather large value, which then remains constant as the tide continues to rise.

If we look at the effect of this on the bay tide response -- here the ocean tide again is solid, the bay tide is dashed -- we have the bay tide following reasonably closely to the ocean tide until that time that the islands are flooded. At that time, the rather large cross-sectional area of the bay means that the tide cannot keep up, and you get a larger difference in elevation between the two.

Now, this goes on until approximately the time that the bay and ocean water levels are equal on the falling ocean tide. And from that point on, the bay tide responds rather quickly to the ocean tide. Well, what this produces is a time asymmetry in the flow through the inlet. Here's our period of flood tide in this area and over here, but our ebb tide occurs only in this period. So we have a duration of ebb which is much less than that of flood. The result, in order to maintain continuity, is that the maximum velocities of the ebb must be larger than the flood. Since sediment transport is proportional to the power of the velocity, we have an ebb dominated sediment system. That's one mechanism by which ebb dominance can occur.

Another mechanism that can produce flood versus ebb predominance is the production of bay tide harmonics or overtides. These are distortions in the idealized bay tide curve due to nonlinear effects primarily related to the variable cross-sectional area of the inlet and the effects of friction on the propagation of the tide into the estuary, and with some minor effects of advection and momentum.

Let's look at the results of a field study conducted by a Dr. Aubrey at Woods Hole. The area of investigation was Nauset Inlet, Cape Cod, and we'll look at the characteristics of the harmonics, looking at the ocean tide characteristics, and then at a tide gauge in Nauset Bay, way inside the inlet.

If we look a spectral analysis of the long term time series of water surface elevation at the ocean site, we see that the dominant cycle here is the M2 tide, diurnal lunar tidal component. Of particular importance are the harmonics of the diurnal lunar period, M4 and M6. Note that the ratio M4 to M2 is a very small number as is the M6 to M2.

If we move up to the Nauset Bay location, we see that the harmonics have drastically increased in importance. The

M4 over M2 is increased by a factor of 50, and the M6 over M2 is increased by a factor of ten. So the propagation of the tide through the inlet has magnified selected components of the tide curve, which were small in the ocean tide. What is the result of this? The result is a distortion of the bay tide compared to the ocean. And this distortion is another way to produce ebb or flood predominance in the inlet.

In this particular inlet, the maximum velocities are associated with the flood currents shown here, admittedly not large but over the long term large enough to produce a flood dominated regime.

In this slide of the inlet, you can see the very well developed flood tidal deltas. There is a great deal of sand in this area. There is some, of course, manifestation of that in the ebb delta. It's fairly well developed, but the flow is flood dominated.

Now, this also occurs in the North Carolina area at Drum Inlet, which has a very poorly developed ebb tide delta but a very well developed flood tidal delta. Although we have no velocity records, we can conclude that there is a flood predominance due to the resulting morphological shape.

Now, in areas of the type that I mentioned at the start where there is a highly channelized bay with marshes that overtop at some stage of the tide, I indicated an ebb dominance. Such inlets and estuaries occur in the South Carolina region. This is North Inlet, South Carolina, and this is a portion of the ebb tidal delta. There is considerable sand seaward of this as well, and the measurements made here by the University of South Carolina indicate a very strong ebb dominance of flow produced by distortion in the bay tide current.

So the hydraulics are important in controlling the sediment response and shape of the inlet. In addition, waves are also important. For instance, they mold and shape the ebb tidal delta. They control the position of the thalweg, the deepest part of the channel cutting through that delta, as I'll discuss in a moment. And waves also are primary cause of sediment transport from beaches on either side toward the inlet.

What are the results of these actions? Well, first of all in looking at the characteristic morphology of inlets, we can classify them into four basic types, depending on their offset. First of all, we have the overlapping offset type where there is a great deal of sand available for transport. Wave action is almost all in one direction, in this case from right to left, producing an overlap of the seaward portion of the barrier island compared to the other one.

In the updrift offset case, the updrift island is further seaward, i.e. offset further seaward than the downdrift island.

In this slide of a downdrift offset inlet, there is a very large bulbous form on the downdrift island, which is offset seaward from the relatively minor development of the updrift island. Looking at some examples of this, Fire Island Inlet, New York, which Duncan showed previously, is the best example of an overlapping inlet. An updrift offset inlet, Ocean City, Maryland, was created by a hurricane in 1933. Jetty construction by the Corps in 1934 produced this fillet north or updrift of the jetty.

Severe erosion and rapid transgression of the northern end of Assateague Island produced this significant updrift offset.

Absecon Inlet, New Jersey, is a downdrift offset. Notice the roughly thousand foot of separation between the shorelines. And a negligible offset inlet, Drum Inlet again, where the wave driven longshore sediment transport rates are approximately equally balanced between leftward and rightward movement.

Now, lets look at the effects of waves on inlets stability. First of all, inlets can be stable in one or two ways, either geographically or geometrically. By geographically we're talking about an inlet that remains in one place. Most of the uncontrolled inlets do not. This is an inlet in Texas which migrates from right to left.

Note this island as a feature that remains constant. The inlet was open in 1943, 1953, and 1958, but finally closed in 1960. The attempts of a few fishermen to create an inlet in 1959 still remain a year after. This inlet stayed opened about three days after they cut it thruogh.

But hurricanes are very effective agents in recreating the inlet, generally at it's original location. This slide was taken a year later, in 1961. Here's the island that we retained for reference. This pattern is typical of many small inlets on sandy coasts.

We've also investigated the effects of waves and currents on inlets which have been jettied. We conducted an analysis of just about all the inlets in the United States that had been jettied in the late 1800s and early 1900s in order to try and develop a generalized picture of the response.

In this case, Masonboro Inlet, North Carolina, the jetty was constructed between 1965 and 1966. The original channel went something like this. There was a navigation channel dredged in 1966 in this area. Within the next three years that channel migrated rapidly toward the jetty.

The same type of thing happened at the Umpqua River entrance in Oregon. The jetty was constructed in a nine year period with prejetty location of the channel roughly in this configuration. After construction, the 1927 line shows that the channel moved rapidly toward the jetty. Both these channels at Masonboro and the Umpqua River remained in those positions until further actions were taken to move them.

Here we have an idealized model of channel migration toward a single updrift jetty. The net longshore sediment transport is moving from right to left, and shoal forms on the downdrift side, with a fillet against the jetty. The channel will migrate very rapidly towards the jetty, and the downdrift beach will erode.

This type of information has been used in plans for the Oregon Inlet jetty improvements. The Corps has timed the construction of the jetty such that the downdrift jetty would be built first. After a two year period to allow the channel to move against the jetty, the north jetty would be built.

In the case of a single downdrift jetty, the wave driven sediment transport is much greater than in the previous case. The migration rate is more rapid toward the jetty, although the end result is the same, with the channel right along the

rocks.

Now, in terms of the geometric stability of an inlet, two major studies have been conducted -- O'Brien's early work in the 1930's and Jarrett's work in the late 1970's. Both found that there was a very good relationship between the tidal prism (volume of water passing through an inlet) and the inlet's cross-section area. Here we're looking at jettied inlet's versus nonjettied inlets. For nonjettied inlets, the slope of the line is slightly different than for jettied inlets, since wave effects reduce the cross-sectional area for a given tidal prism. So the stability is related to the degree of protection that you provide the throat of the inlet.

Finally, I will present a few design considerations for those engineers in the audience that are involved in the planning of coastal projects at inlets. First of all, a historical analysis must be done of the area that you're interested in. Detailed field studies should be carried out to determine the ebb and flood predominance of the inlet, the sediment transport patterns and so on. Model predictions are usually useful, and either numerical, or in some cases physical, models should be applied to determine the effects of your planned activities on the estuaries and inlets involved.

Now, just a few historical lessons and comments. This is Barnegat Inlet, New Jersey. The best information I have on the design of this particular inlet is that a coastal engineer from the Great Lakes was transferred to the New Jersey coast. The arrowhead breakwater design shown is common and very effective in the Great Lakes for reducing wave action, so the design was simply copied for this Atlantic coast inlet. However, the Great Lakes have no tidal currents. So in neglecting to consider all possible forces, a monstrosity was created which has plagued the Corps for the last 50 years. There is no efficient hydraulic flow through an arrowhead breakwater like this, and a great deal of sedimentation occurs within the channel.

The point is that in developing a design plan, be careful about applying a solution simply because it was successful in one area.

In conducting field studies, electronic instrumentation to measure tides and currents has improved greatly within the last five or six years. This slide of Dave Aubrey's crew at Nauset Inlet epitomizes a high tech approach to measuring and analyzing ocean and bay tides. Electro magnetic current meters are mounted on the bottom and digital recording tide gauges are installed at several sites for spectral analysis of ocean and bay tides. It's not enough these days to simply take propeller meters out in an inlet and make a few flow measurement. The field studies should be comprehensive. They should be over at least a lunar tidal cycle, and they should be conducted by trained personnel.

Finally, in the use and application of models, I would urge you to calibrate your models carefully and then verify them even more carefully. One of the results of our studies were that physical models can be quite useful, when properly applied. This is an actual aerial photograph of Masonboro Inlet, with a jetty here and a large shoal here. We placed anchored dye packets at these locations during a flood flow, and then took sequential

aerial photographs which showed the movement of water over the shoal and into the inlet.

We recreated that in a physical model. First of all, we ran it without any wave effects. The model results on the shoal are rather good. In the offshore area (water depth about 15 feet) they are not. When we ran the model with waves, the flow in this area improved greatly, and this improvement was also observed throughout other tidal stages. Thus, it's important to reproduce the conditions which affect the flow in their entirety in such models.

In summary, inlet flows and shapes are controlled by tides and modified by waves. We have found that we can classify inlets based on common characteristics relating to their physical shape and size, their stability and their hydraulic characteristics. We know that inlet design must consider both the generalized and unique aspects of any situation, and that models are useful to improved designs of inlets.

MR. DOUCAKIS: Thank you, Curt.

The next speaker is Dr. Larry Daggett, who is a hydraulic engineer for the Waterways Experiment Station, and Larry's topic is Navigation Improvement Model Study of Portsmouth Harbor, New Hampshire.

NAVIGATION IMPROVEMENT MODEL STUDY OF PORTSMOUTH HARBOR, NEW HAMPSHIRE

DR. DAGGETT: I am going to change our direction considerably here and go into another area of the Corps responsibility, that of navigation. I'm also going to be talking about a project that has passed the feasibility study stage and we're going into a new study stage, and this study has only just begun. So what I'm going to be talking about is more plans and a little bit of project accomplishment. But the real purpose of this talk is to introduce a kind of new technique that's now available to us in conducting navigation studies, particularly where maneuverability problems are a primary consideration, and the piloting problems are important.

I'm going to be talking about a particular study on the navigation aspects, the maneuvering aspects of Portsmouth Harbor. It's located between Boston and Portland, and it is one of the primary ports in that region.

A little closer view of the layout of the navigation channel project shows that it is a very twisty type of a channel. There are three bridges that cross this river area. This is an enlargement of the area of the study where we're going to be looking at the improvements and has a layout of the areas that are to be improved.

This particular project has a number of aspects that make navigation very difficult in here. First of all, the products that are the primary commodities being brought into this port are petroleum products. This area has a lot of rock in it, so that the bottom and banks are hard. Any accidents could have a catastrophic type impact on the area.

These bridges are lift bridges, the bottom two bridges, that is. The upper bridge (the Maine-New Hampshire Bridge) in particular is narrow and has an angle to the channel.

It creates a major problem in navigating the channel.

The tides here are relatively large, and because of this the currents are high. This makes navigating this area difficult, and the general trend of the fleet carrying petroleum products has been towards larger vessels going from about 30,000 dead weight ton tankers into the class of 40 to 45,000 with some larger tankers calling on this port. This makes the handling problems even more critical.

The project calls for widening in this area (downstream of the Maine-New Hampshire Bridge) where there's a maneuvering problem getting into this bridge. Also, this bridge can become jammed in some cases as it is being raised which makes it impassable for the ships. They have to have some emergency maneuvering room. In this area (at Henderson Point) there are some strong currents and maneuvering is difficult here, so we're looking at widening this portion of the channel to give them some more maneuvering room.

The channel is 35 feet deep, and the ships that call are normally loaded to a draft around 37 feet. So they are using the flood tide condition to come in to give them extra draft under the keel of the vessel. This also makes it difficult to maneuver because there is a following current that's pushing the ship in the channel. This it more difficult for steerage.

This is another view of the orientation of the bridge and the channel turns. This is one of the areas we're looking at widening. This bridge is a very narrow bridge to maneuver through. And this shows the kind of angle at which the vessel approaches the bridge. As it moves closer, there is a sudden swing of the stern of the vessel around to go through the bridge.

In order to do this study because of the very strong influence of the currents, we had to get a model of the currents so that we could put this into the ship simulation model. We've also had to do some prototype measurements to provide the information needed to develop the numerical model which we'll be doing as a hydrodynamic math model. Then we will input those currents for the conditions that we'll be testing into a ship simulator facility.

Just a quick look at the prototype. We have conducted the prototype data collection. We did it on the 12th of September and continued some monitoring into the 25th of September which produced an 8-foot and a 12-foot tide range, respectively. This shows that we did have the long term and then the shorter term period, a 15-hour period where we did an intensive survey of the area. We used several pieces of equipment, tide gauges, velocity, salinity measurement equipment, and ENDECO 105 meters, which were installed for the longer period of monitoring.

This is a picture of the ENDECO meter, which is a velocity meter and also takes salinity samplings. It was tethered from a moored string buoy anchored at several locations. This is a picture of some of the apparatus that the hydraulics lab has for doing prototype measurement studies and shows the velocity meter and the direction indicator that we use for these surveys. We also have this apparatus that can be amounted fairly quickly on board the vessels involved in the survey.

This slide shows the vessels, as they went through a

period of sampling across the ranges that they worked, moored to the anchor buoy system and then with the gauge lowered into the water. They made measurements at several depths and then repeated this across the transect.

This is a picture of one of the tide gauges being installed, and the tide gauge installed at another installation.

This is an unusual prototype data collection activity because we got some very good assistance from the New England Division. They actually surveyed in the location of the moored strings, the places where we were taking our sampling and the tide gauges so that we have a very good control on this data collection effort. This is unusual for prototype data.

This is a slide that shows the locations of the data collection activities. This is the upper range of the numerical model, and this will be our lower boundary. These are the two bridges of primary concern, and the primary study area is right in this region. We took several intensive sample ranges in between our two boundaries that we're using for our numerical model and took several ranges to define flows back behind these islands and through some of the inlets to the back bay areas.

Now, we're going to discuss the hydrodynamic modeling at this time. We're in the grid development phase right now. We've begun some of the initial grid testing. In the next few months we'll be going into the calibration and base plan testing. We will then extract currents that will be put into the ship simulation study.

This is the initial grid development that we have done for this area, and you can see that we're using a finite element model which is part of what we call the 2 system. RMA2 is the hydrodynamic portion of that system. You can see that we've concentrated the elements into the channel area, and in developing the grid have tried to take into account the limits of the channel as it exists now and with the planned improvements.

After we calculate these current patterns for the desired conditions, they will go into a simulation model of the ship hydrodynamics. This model will compute how the ship responds to the controls that the pilot will give it, how it responds to the current pattern, according to the position at which it's located and the orientation of it to the currents. It also responds to the bank effects. As it gets close to the banks there can be a bank suction or bank cushioning that will take place. And it also responds to shallow water conditions. As vessels get into shallower water, there is less clearance under the keel. The flow around the hull changes. The control surfaces respond differently. The hull responds differently. In fact, it usually becomes much more sluggish in terms of its response.

You now see a slide showing CAORF. This is a joint study effort that is being conducted by WES and CAORF, which is the Maritime Administration's Computer Aided Operations Research Facility. This is a full bridge ship simulation facility. Using this simulator we're going to be looking at the degree of improvement that we will get in the navigability of this reach with the new proposed channel alignment.

We haven't gone far enough in the development of this project to be able to show you the visual scene as it would be seen from the bridge in the simulator for this particular

project, but this slide shows another area and should give you an idea of the kind of picture that can be generated with computer generated imagery of another typical traffic bridge going across the channel as viewed from the ship's bridge while standing where the pilot would be standing. This is a fish eye view of the bridge facilities that are available at CAORF. They have a wraparound projection screen on which a fairly good peripheral view of the harbor areas is available. They have a full range of ship bridge equipment available at the simulator.

There is the possibility that if we see continued problems in getting through the bridge area that the study may have to be expanded to look at the possibility of improvements being made to the bridge itself. That will be done only if it's necessary. One of the goals of this study is to see if the channel dimensions that are being planned for the channel modifications are adequate, if it needs to be that big. Maybe we don't need to go quite as large, or maybe it's inadequate. Or, maybe there are some other places that we need to make an improvement.

This is a review of those areas that we were looking at for improvements, the Area 1 and the Area 3.

The tests will be conducted with the actual pilots from the area. It turns out that as difficult as that area is to navigate, you would think there would have been a lot more accidents, and I'm surprised that they have as good a record that they have. Apparently it's due to the very skilled nature of the pilots involved. There are only 3 pilots that operate in this area bringing in these large vessels. All three of them will be participating in the study. We're going to be modeling both day and night conditions. This identifies some of the components that have to go into the data base development of the simulator.

We'll have to develop visual scenes of the harbor area for both day and night. We'll be doing testing with and without the planned condition. What has to go into the simulator will be the channel definition in terms of geometry, the currents, (by using the numerical model, we can test changes in the currents that will occur due to the change in channel geometry), the banks (how they are shaped makes a difference in how the vessel responds) and the depths of the water in that area. There also has to be a development of a representative design vessel which is going to be the 40,000 dead weight ton tanker.

This is a table of the testing conditions. The modified bridge condition is a special condition that may be added. Right now it's not planned to do that as part of the testing program. The failure test is a test to see what would happen if the ship loses power or if the bridge becomes jammed and the ship has to do some maneuvering in that area below the bridge. The currents will try to push it into the bridge; it's been moving that way and has momentum. The pilots will have to perform some emergency operations to be able to stop their movement toward the bridge, turn around, and either find a landing facility that they can dock against or exit out of the channel.

From the ship simulator we can get tracking information about how the vessel has stayed within the channel, what kind of clearances are available, what kind of control commands were required to be issued, how much steering was

required, just how difficult was it, how much reserve rudder do they have for emergency type conditions, and (by looking at a whole group of these) we can come up with some statistical boundaries of the ship path itself for the tested condition. Then we can evaluate the adequacy of the design.

The main thing I wanted to do was introduce the procedure and the tool, a technique that's available now for looking at some of our navigation projects and being able to optimize the channel design. In this case, the construction costs are the dominant feature, in that the rock that would have to be cut is a very expensive type of construction. Any reduction in the size of the area that has to be excavated could be a major savings, as well as the requirements on the disposal of the material will be reduced.

Maintenance is not much of a problem here. In other cases, though, maintenance could become a major issue and be another reason for looking at optimizing our channel size. Thank you.

MR. DOUCAKIS: Thank you, Larry. The next stage is the discussion stage. So if we could have the previous three speakers sit right over here. Do we have any questions from the audience?

DR. KELLEY: My name is Joe Kelley, I work for the Maine Geological Survey. The first two speakers talked about flood and ebb dominance in tidal inlets. It seems to me that there would be two ways to evaluate the dominance of tidal currents, either by measuring the volume of sand which comprise the delta, the flood or ebb tidal deltas, or by in some way carefully measuring the flow velocities in one direction or the other.

It seemed to me specifically in Duncan's presentation that you looked at some point bars along the river and added them up as part of the volume of sand comprising the flood tidal delta and could reasonably then conclude that you had a flood dominated system. And it seemed to neglect the swash platforms, specifically off Ogunquit Beach, which might have been part of the ebb tidal delta. I wonder have you used any seismic profiling or anything to really figure out what the thickness of sediment is in the tidal deltas? And were you really intending to include the point bars and not include the swash platform?

DR. FITZGERALD: Well, Joe, you've said a lot. First of all, you can have ebb dominated inlets with flood tidal deltas. The fact that you have flood or ebb tidal deltas does not dictate whether the inlet is flood or ebb dominant. That case that I showed at Bass River Inlet is strongly flood dominant because we've measured the current velocity. What I was trying to impress upon you was that yes, I did point out two flood tidal deltas because they were, had the horseshoe shape and react very much like flood tidal deltas. Also I was trying to impress upon you the amount of sand that has filled those channels. But getting back to whether we have done seismic work in these areas, no, not yet.

DR. KELLEY: Okay, the tidal current velocities, I noticed only I think two dates of times when you went out and made measurement, of current velocities in Maine inlets. One was in January and the other I think was in the summer. These are times

of minimum river contributions to these system. I would wonder, do you think you'd obtain the same results in these rivers if you measured the velocities at time of peak river contribution; that is, either in the fall or in the spring when the rivers are really making their only significant seasonal contributions?

DR. FITZGERALD: I'm very glad you brought that up. Although these tidal inlets are all called rivers, they really aren't rivers at all. They have no statified flow except for extreme discharge events that you're discussing. When you look at a tidal range of 8 to 9, 10 feet in these areas, the amount of fresh water discharge is going have very little effect in these regions. When you have in these tidal inlets -- we didn't show all of our data points. But when you of duration differences of two to three hours, the seasonality of these inlets is not going to change the hydraulics of them considerably.

MR. MASON: If I might comment. In fact during those periods of high fresh water discharge, there is a mechanism for flood dominated bottom transport of the material due to density currents. So it's not a necessary result that you get ebb dominance in the sediment transport patterns just because you have a lot of fresh water outflow.

MR. DOUCAKIS: Any further questions?

MS. ARBUCKLE: I'm Jane Arbuckle from the Maine Audubon Society. The previous talk indicates, and we all know that the Corps certainly reviews and tries to improve certain projects. And I'm wondering if there is any systematic review of old projects given current knowledge and better technology. And if it's found that a certain project really was a bad mistake, how does the Corps deal with those mistakes? For instance, are breakwater ever removed if you find that in fact the flows are all wrong and it's causing more harm than good?

MR. BRUHA: Do we have any volunteers from anybody?

MR. MASON: Yes, Tom, I'll take a shot at it. I think it's the nature of the district's and division's business that they don't spend a lot of time looking at old projects.

In the research laboratories we have done that to some extend, the study I mentioned looking at channel response. In planning coastal projects of an unique nature, sometimes the past behavior of similar projects have been looked at. And I'll give you an example. Masonboro Inlet was the first jetty to use a weir, a low crested wall to allow sediment to coming into the inlet and then be bypassed from there. People looked at the response of the inlet and the sedimentation patterns resulting from that kind of design and said, well, let's do an adjustable weir. And Murrell's Inlet, South Carolina, was built with a weir that had holes in it that could be filled or pulled out to allow sediment either to come in or to stockpile on the north side of the inlet.

So in terms of using the results of past projects to better design future ones, it does happen. Unfortunately not enough probably.

MR. DONOVAN: I'm Bill Donovan from the Chief's office of the Army Corps. The comment or the question the young women raised I think is a very pertinent one. The best way I might be able to answer that is that it doesn't just relate to the coastal concern but all sorts of planning and engineering concerns

in the Corps' projects and the projects of many other federal agencies.

I think it's what we would call ex-poste review or ex-poste studies. And this question and observation has been made many times in almost any major studies of limitations and deficiencies or ways to improve federal planning in the water resources area generally by many types of studies over the past years. That's usually been incorporated. You should do better ex-poste studies and so forth.

And I think just as a general concept and a general idea all professionals in the Corps and I'm sure elsewhere, research people and so forth, would love for us to be easily able to do ex-poste studies and learn either from our mistakes or from the improvements that have come from the improvements and mistakes of the various scientific arts. The unfortunate part about this is generally speaking Congress will not support the funds need for ex-poste studies because they do not necessarily come cheap. Now you can learn some things are very obvious, and there's a good example of the Barnegat Inlet posted on the Board. We could learn from looking at that and from that transfer, that experience many, many years ago from the Great Lakes into the New Jersey coast.

And of course, to rectify or clear up that unfortunate design for that although it was well intended at the time, even if we've learned, a lot of studies are going on on that now. That's going to be a costly correction or new adaptation. But I think in general, we'd all like to do ex-poste studies. They just don't come cheap. You don't get the monies to do them is really fundamentally the problem. So in an on-going operational context, some adjustments and things can be made as far as really studying the things in total.

Of course, these comments for ex-poste studies were even made long before the event of the environment thrust of the environmental area, and you know and I know and we all know there's a still a great deal to be learned in this newer area, and we're only coming to grips with it fairly intensively in the last 10, 15 years.

So I think your question is well raised. I don't think it's easily answered. And I'd just try to approach it from the broader view of the limitations of going about ex-poste studies, getting the support to do that. Congress is only looking to the future unfortunately. They don't want to look back and study and learn from experience and provide the funds to do so.

MR. DOUKAKIS: Thank you, Bill.

DR. DAGGETT: I just might comment. I know of a few cases where there have been some changes made in the past few -- well, I don't know if it's the past few years, but I know one discussion that I've heard where a dike, for instance, was put in and didn't function as it was expected to. And was removed. It's not widely broadcast or advertised but there have been some changes. That's not a cheap process to do. There was a lot of consideration given in terms of whether or not it was to take place or not.

In some of the research areas I know that we have talked with the availability of being able to look at these navigation projects in a little more detail. There are changes that occur. For instance the Corps has changed the dredging

policy in the upper Mississippi in response to environmental concerns and dredging costs, increases and some of the problems with disposal of dredge material. And they have actually changed their dredging policy which results in reduced channel dimensions. And we just recently conducted a study because that was done in response to some environmental and economic considerations, the converse question came up, well, what are you going to have negative impacts on navigation, and we are just completing the study looking at what impacts this channel change in terms of dimensions would have on the maneuvering, the safety of operations.

We've also discussed with the Chief's office about some possible studies looking at the, even though the channels are authorized for certain sizes as far as the maintenance of the channels and the possibilities of reducing or maybe needing to increase some of those sizes. So I think we do look at some of these projects as they need to improved are or as we identify problems with them.

MR. DOUCAKIS: Any further questions from the audience?

MR. RICHARDSON: I'm Tom Richardson. I'm with the Coastal Engineering Research Center. There are at least two mechanisms existing right now through the R&D community for addressing just this particular concern. The primary one is called Monitoring Completed Coastal Projects Program, and it's a program that is been in existence for several years now and is healthy. Of course it could always use more funding.

The purpose of is it to look at newly constructed coastal projects, selected coastal projects, monitor them for a certain period of time after they are constructed, and determine just how well they performed in accordance with what the design predictions were. So it's a modest effort to close that design loop where you build a project and walk away from it and never ever make any general observations.

The second mechanism is a research work unit called the Evaluation of Navigation Shore Protection Structures. It's been in existence for a number of years and I hope will continue for a number of years. It's purpose is to look at more specific problems that crop up with newly constructed coastal projects. If a particular aspect of a project, for instance, isn't performing as it should have been or as it was predicted, this work unit provides a quick response mechanism for monitoring that and trying to determine what the cause of its nonperformance is. And then to develop some general design guidelines that can be used for subsequent cases.

So it's not a completely unaddressed area in the Corps, although of course, it can always use quite a bit more funding than we have available at the present.

MR. DOUCAKIS: Thank you. Before we adjourn for lunch, Duncan Fitzgerald has something he would like to add.

PART II OF TIDAL INLET PRESENTATION
EFFECTS OF THE BAY OF FUNDY PROJECT
ON THE TIDAL INLETS OF MAINE

INTRODUCTION

DR. FITZGERALD: The Bay of Fundy Project is expected to increase tidal range by 12 inches in the Gulf of Maine along the central and southern Maine coast. This means the tide will be 6 inches lower at low tide and 6 inches higher at high tide. My discussuion will be divided into how this increase in tidal range will influence small tidal inlets (width less than 100m) and then large tidal inlets (width greater than 100m).

INFLUENCE TO SMALL INLETS

The backbarrier environment of small tidal inlets consists of primarily spartina marsh with a few tidal creeks and almost no open water areas. At low tide these tidal channels are mostly empty and the marshes are well exposed. At high tide while the creeks have filled with water the marsh surface is still mostly dry. It is only during spring high tide conditions that tidal channels reach bank full stage and the marshes are flooded.

Now let us consider what will happen in the backbarrier setting. The increase in ocean tidal range will cause higher water levels behind the inlets. Consequently, the marshes will be flooded not only at times of large spring tides but the marshes may be flooded during mean tidal ranges as well. Because this situation drastically increases the size of the bay, it is expected that when the tide levels do exceed the height of the marsh that the tidal prisms will be significantly increased. Measurements at Ogunquit River Inlet indicate that a 4-5 inch increase in the height of the high tide will increase the tidal prism (the volume of water that goes into and out of the tidal inlet) by 15-20 percent. Calculations for other small inlets in Maine show similar increases.

The increase in tidal prism in the backbarrier environment will result in the readjustment of the drainage channels. If the channels have to carry more water, they are going to enlarge slightly. It may also be expected that the rate of channel meandering will increase and that meander cutoffs would occur more frequently.

There is a well known relationship that relates the amount of water going into and out of the tidal inlet -- (tidal prism) -- and the inlet throat cross-sectional area. This is known as O'Brien's relationship. If tidal prisms increase at an inlet, this will cause the scouring of a larger cross-sectonal area channel. At inlets in Maine the increase in the size of the inlet throat will result in erosion of the spit, and perhaps some deepening of the inlet channel. Because small inlets in Maine tend to be flood dominant, tidal currents will also transport more sand onto the flood-tidal deltas.

The most dramatic effect that is going to happen to these inlets is that the ebb-tidal deltas will enlarge. The ebb-tidal deltas will enlarge due to the increase in tidal prism. In an investigation by Walton and Adams in 1976, they showed that the size of the outer bar, or as geologists call it the ebb-tidal delta, is directly related to the volume of the tidal prism. As

the tidal prism increases, the volume of the ebb-tidal delta will increase.

In more desrciptive terms, what the ebb-tidal delta actually represents is an equilibrium relationship in sediment transport. Tidal currents transport sediment offshore and wave-generated currents transport sediment back onshore. If one of these parameters changes and that is what is happening by increasing the tidal prism, then the sediment transported offshore by tidal currents will increase. Consequently, more sand is going to accumulate on the ebb-tidal delta. This increase in the size of the ebb-tidal delta neccessitates a supply of sediment from somewhere.

As mentioned earlier, at Ogunquit River inlet, the tidal prism is going to increase by about 15 to 20 percent. When the tidal prism increases, some sand will be eroded from the spit and some sand may be eroded from the channel. However, this sand will not meet the needs of an ebb-tidal delta that is increasing by 50,000 cubic meters. Additional sand is obviously going to come from the nearby beaches.

LARGE INLETS

Large tidal inlets in Maine will be affected in the same manner as the small inlets. The increase in the tidal range will increase the inlet tidal prisms. To discuss the changes that will occur as a result of the tidal prism increases, the Kennebec River Estuary will be used as an example. The Kennebec River Estuary is located along the peninsula coast of Maine adjacent to Popham Beach. Due to the lack of published data, the tidal prism of the Kennebec River Estuary was determined from channel cross sections. Using coast charts of the region, the average channel cross-sectional area was computed to be 110,000 square meters. Plotting this value on O'Brien's curve, the tidal prism was calculated to be 1.13 billion cubic meters. The tidal prism of the Kennebec River is comparable to that of San Francisco Bay.

The tidal prism data can be used to determine the size of the ebb-tidal delta. Using Walton and Adam's equation, the volume was calculated to be 870 million cubic meters.

The volume of the ebb-tidal delta was also computed directly from the ebb-tidal delta bathymetry. This technique, designed by Dean and Walton in 1975, compares the existing bathymetry of an ebb-tidal delta to the bathymetry that would exist if the tidal inlet were not there. Using this methodology, the volume of the delta was determined to be 1.06 billion cubic meters. The fact that the two values of the ebb-tidal delta volume are fairly close (determined by very different methods) indicates that the tidal prism that was originally calculated from Jarrett's curves is fairly accurate.

Let us consider what will happen to the ebb-tidal delta with the increase in tidal range. Taking into account the attenuation of the tidal wave, the increase in tidal range in the Kennebec River by 30cm will increase the tidal prism by 5-10 percent. If the lower figure of 5 percent increase in tidal prism is used, which is a very conservative estimate, it is calculated (using Walton and Adam's equations) that the ebb-tidal delta would increase in volume by 57 million cubic meters.

The question arises: where is the sand going to come from? At first, it may seem as if the sediment will simply

be scoured from the channel bottom. However, if it is assumed that the Kennebec River channel is eroded an additional depth of 2m from the mouth of the river to Merry Meeting Bay (about 14 miles), that will account for only 20 percent of the sand that is predicted to be deposited on the ebb-tidal delta.

If the river will only account for a small portion of the sand that will accumulate on the ebb-tidal delta due to the increase in tidal prism, then the rest of that sand has got to come from the adjacent beaches.

CONCLUSIONS

In conclusion, the Bay of Fundy tidal project will cause an increase in tidal prism of Maine's tidal inlets. This, in turn, will cause an increase in the size of the ebb-tidal deltas. That sand will come from backbarrier tidal channels, the inlet throat and most importantly from the erosion of nearby beaches. At larger tidal inlets, this is going to cause catastophic erosion of adjacent shorelines. The factor that has not been computed in this analysis is how fast this enlargement of the ebb-tidal deltas will take place.

MR. DOUCAKIS: Again for those who have meal tickets, lunch will be served in the adjoining room and there is no assigned seating. For people who do not have meal tickets, they are free to eat in the dining room. We'll meet back here at 1:30 for the next topic. Thank you.

(Luncheon recess).

AFTERNOON SESSION

DR. FESSENDEN: Welcome to the afternoon session, ladies and gentlemen. My name is Frank Fessenden. Before we get going this afternoon, I have a couple of announcements. First of all, up in the poster session room, there are still several prints of paper, there are still several outlines that if any of you would be interested in picking them up, please feel free.

Also, this is a special notice to the speakers. Because of the technical nature of many of these talks, we would very much like to have submit to Tom Bruha, either now or mail to him later on, a copy of the talk that you gave today. The reason for this is because as we have announced, we are going to try and get out to everyone a copy of the transcript of these proceedings and many of the names, the technical terms and so forth are not familiar to our stenographer, although she knows just about everything else, but there are a couple that she simply can't get down. So if you could mail a copy of your presentation, that would be extremely helpful.

One other announcement. This is a correction on time. Previously the evening session was announced to be begin at 8 o'clock. This is not true. It will begin at 7:30 or 1930 as the military like to say. So the evening session is at 7:30 this evening obviously. And this also puts a little bit more pressure on our getting right to supper because as Tom mentioned this morning, the service is very gracious and have slow in some cases.

Also one other announcement, Duncan Fitzgerald has taken the catastrophic step of volunteering to join the discussion panel after this particular talk. So those few of you who may have something to say to him will have your opportunity.

I think I'll taken care of all of the announcements. I'd like to remind the speakers once again of our lighting system over here. You have two minutes when the green light comes on. You have one minute when the amber light comes on and then some sort of self-destructing missle I think happens when the red light comes on.

This afternoon's session is on rising sea level. The first speaker of the series is Ms. Barbara Braatz from the Woods Hole Oceanographic Institute who will talking on Sea Level Rise Over the Past Century.

SEA LEVEL RISE OVER THE PAST CENTURY

MS. BRAATZ: The talk I am about to present is on work that has been done by David Aubrey and K.O. Emery at the Woods Hole Oceanographic Institution. I recently became involved in this work, so that when Dave was unable to come to this meeting, he asked me to present this talk for him.

What we are trying to do is to estimate past changes in global sea level, and then use these estimates to predict future trends in sea level. If we can define how sea level has changed in the past 100 years, then perhaps we can use this information as an early warning signal or a detector of future changes in sea level, particularly those changes related to global warming due to the greenhouse effect. We have a good idea as to how much additional carbon dioxide has been pumped into the atmosphere over the past 100 years due to deforestation and

burning of fossil fuels. What has been the effect of this additional atmospheric carbon dioxide on eustatic sea level? Has level risen over the past century? If sea level has risen, what is that rate of rise, and is that rate increasing with time?

We are looking at long-term global sea level trends; long term in an oceanographic, rather than a geologic, sense. We are looking at time scales on the order of a year or more, and space scales as small as possible, given the data set available.

Our data base consists of tide gauge stations located around the globe. These tide gauge records are averaged hourly for each year, to give us a mean annual sea level for each station. There are approximately 300 stations in the world. Of these, some are unavailable for analysis, others have records which are too short or too interrupted for use, and others are no longer monitored, leaving approximately 250 usable stations. Unfortunately, approximately 92 percent of these stations are in the northern hemisphere, which gives a strong bias to the data set. I will come back to this problem later in the talk.

A number of researchers over the past 40 years or so have come up with various estimates of the amount of global sea level rise over the past century. One must remember that these are global, rather than regional, averages, and that these are measures of relative movements of sea level. In other words, we do not know whether the land is subsiding, or the sea is rising. MOst of the results of earlier studies cluster around 11 to 12cm. This is encouraging, since these studies used data sets with different stations over different time spans. The more recent studies of Emery and Barnett show greater amounts of sea level rise. These studies used more recent tide gauge data, indicating that perhaps the rate of sea level rise has increased over the past century. In fact, Barnett, in 1984, increased his estimate to 20cm.

We want to separate the regional behavior of the sea level from coherent, global trends. I will talk of eustatic changes, but one must remember that eustatic changes will not be equivalent over the globe. If a pile of water is dumped into the ocean, the amount of sea level rise will not be the same throughout the world because of equipotential surfaces. So what we are looking for are coherent, global changes of varying magnitude. Therefore, there is no need to average to obtain a single, global rate of sea level rise. Instead, we want to determine how sea level varies in time and in space in a regional sense, and thereby obtain more information about sea level.

Why is sea level so difficult to unravel? It involves a great many variables. In some regions of the globe, tectonic effects, such as plate motions, play a very important role in the sea level signal. Later I will show you some results from a region where the tectonic signal dominates what we see in sea level changes. Isostatic effects, such as glacial rebound, can also play an important role. I will show you results from another region where this is the case. Oceanographic effect, such as the Southern Oscillation/El Nino, can play a very complicated role in the sea level signal. We know that the El Nino event causes warming, and consequent steric expansion, of the South Pacific Ocean. This causes a local sea level rise, that may have global consequences. Oceanographic effects are particularly

complex, high frequency signals. Lastly, what are the atmospheric effects on sea level? How does increased atmospheric carbon dioxide feed into the oceanographic signal and change sea level? Waht is the global significance of increased atmospheric carbon dioxide?

We know (or at least the data indicate) that sea level has been rising over the last century. It would be very convenient to be able to explain this rise by the melting of the polar ice caps due to atmospheric warming from the greenhouse effect. Unfortunately, researchers in Antarctica believe that the Antarctic ice cap is not decreasing in size, but is, in fact, increasing, extracting water from the oceans at a rate of about 1mm per year. So what is causing the increase in sea level? Melting of Arctic and alpine ice masses? Oceanographic or tectonic effects? This is what we are trying to determine.

Difficulties which are encountered with the data set involve a multiplicity of space and time scales. Some coastlines have a station every 10 miles, some only every 100 miles. We have non-uniform spatial samples. As I said before, 92 percent of the tide gauge stations are in the northern hemisphere. And we have non-uniform temporal samples. Some stations have records that extend back 100 years, some only 30 years.

Because of the non-uniformity of space and time scales in the data set, we have had to use multivariate statistical techniques for the analysis. Specifically, we are using empirical orthogonal function analysis, also known as principal component analysis or eigenfunction analysis. Without going into much detail, I would like to explain the basics of the technique, so that when I show you some results, you will have a better feel for what the numbers represent.

Standard empirical orthogonal function analysis can only be applied to data sets with overlapping time series. The tide gauge data, however, is not continuous. Some records are missing sections at the beginning or end of the period of time we are interested in, as well as a year or more in the middle. In order to use most of the available data, Dave has developed a modified eigenanalysis to handle the data with gaps, without extrapolation or interpolation.

Eigenanalysis separates a data set into orthogonal spatial and temporal modes, thereby most efficiently describing the variability of the data set. Many previous studies have used linear and non-linear regression techniques to analyze this data. Unfortunately, regression techniques provide no information on the spatial and temporal structure of the data. In fact, they impose a subjective shape to sea level curves, and optimally fit the record to that shape.

Briefly, in eigenanalysis, a data set, $n(x,t)$, or sea level which varies in space and time, is decomposed into orthogonal statistical functions called eigenvectors or principal components. Each of these functions has some spatial variability and some temporal variability. So when I show you a plot of a spatial function, there will be a time series associated with it. In other words, every spatial function has a temporal function which shows how the spatial function varies with time.

Now I would like to show you some results from three regions: the first from the east coast of the United States, which

we normally think of as a stable margin; next, the Japanese islands, which are part of a convergent plate system; and last, the Fenno-Scandia region, which has undergone measurable isostatic adjustment since the last glacial maximum.

I would like you to focus on the lower right-hand diagram. The first two spatial eigenfunctions for the United States east coast are plotted (in a relative sense) against the east coast tide gauge stations (in a linear sense). As you can see, there is a great deal of variability in the eigenfunctions along the coastline. If the east coast were purely undergoing a eustatic rise in sea level, we would not expect to see so much structure in the data. The curves would be much simpler.

We can take the dominant spatial eigenfunctions, along with their associated temporal functions, to reconstruct a sea level curve. In the upper portion of this diagram, relative sea level rise in mm per year, determined from the eigenanalysis, is plotted against distance along the east coast, from Cedar Key, Florida on the left to Eastport, Maine on the right. Three distinct trends emerge from the data. The rate of sea level rise shows an increasing trend from Cedar Key to Cape Haterras, a decreasing trend from Cape Hatteras to Cape Cod, then an increasing trend from Boston to Eastport. An attempt to relate this sea level curve to the geology of the region was made in comparing it to the depth to shelfbreak, the assumption being that if this sea level structure has persisted over a long period of time, it would be echoed in the depth to shelfbreak. But as you can see, there is not a consistent correlation between the two curves. We are not sure at present what is causing these three different trends in the sea level along the east coast. It may be part due to isostatic readjustment, but geologists are not certain whether readjustment is still going on. Many believe that glacial rebound in North America occurred quite rapidly after the retreat of the last continental glaciers, and that it would no longer be contributing any detectable signal to sea level. The east coast sea level curves may also be due to the tectonic structure of the continental margin, more specifcally the distance between the tide gauge stations and the hinge line, an area of crustal thinning that resulted from the rifting of the North Atlantic 200 million years ago. Isostatic readjustment as well as hydrostatic loading will have different effects along the coastline depending on the structure beneath. Since these ideas are not cast in concrete, I do not want to go into any more detail, but I would be happy to discuss them with anyone later.

I would like to show you a simlar plot of sea level rise to point out some local effects. Here, relative sea level rise, in mm per year, is plotted against all the United States stations, from Honolulu to Alaska, down the west coast, across the Gulf coast, and then from the Florida Keys up to Maine. The high positive peak of about 5-5.5 mm/yr in the sea level curve occurs at Galveston, Texas, which we know is an area of extensive pore fluid removal and compaction of Quaternary sediments. The subsidence of the land here accounts for the high positive rate of sea level rise. The high negative peak of about -4mm/yr occurs at Yakutat, Alaska. An earthquake occurred here in 1899, which resulted in tectonic uplift of about 14 meters. So at this location, land uplift accounts for the high negative rate of sea

level rise.

We can also look at the temporal eigenfunctions to see how the spatial eigenfunctions vary in time. This is a plot of the 1st and 2nd eigenfunctions plotted against time, from 1920 on the left to 1980 on the right. A linear regression of the first eigenfunction shows an increasing trend with time. But associated with this trend is a great deal of variability. A spectral analysis of the temporal functions will reveal the dominant frequencies in the data. These are the plots of the spectra of the 1st and 2nd eigenfunctions, plotted as relative energy versus period and frequency. In the plot for the first function, there is a peak at the long period end which is probably the long-term eustatic trend in sea level. There are also several higher frequency peaks which may be related to atmospheric or climatic cycles.

Next, I would like to look at an unstable margin, where we know that the plate convergence is occuring. This is a contour plot of the mean annual relative movement of the land in Japan for the last 30 years from the reconstructed eigenfunction data. The Asian mainland is on the left, and the four islands of Japan on the right: Hokkaido, Honshu, Shikoku, and Kyushu. The contours are in mm per year. A relatively simple structure emerges from the data, with the east coast of the islands being submergent, except for one station on the west coast with a high negative value which was the site of a recent earthquake. Around the inland waterway, there is an S-shaped structure to the sea level curves. If Japan were undergoing a purely eustatic sea level rise, one would not expect such structure in the data. But if one looks at the tectonics of the region, one can easily see why such a sea level structure emerges.

This is the same map, but with the tectonic structure of the region overlain. Once again, here is the Asian mainland and the four Japanese islands. These islands are bounded on the east by the Bonin Trench and the Japan Trench, and in the southeast by the Nankai Trough. The Pacific plate in the east is underthrusting the Japanese plate in the west, causing tectonic erosion along the base of the overthrusting plate. This erosion is causing submergence of the eastern margin of the Japanese plate, resulting in a submergent eastern Japanese coastline and an emergent western Japanese coastline. The same motion is occuring in the southeast along Nankai Trough. Here, the Philippine plate is underthrusting the Japanese plate, causing tectonic erosion of the overthrusting plate. These two motions, overlain on one another explain the S-shaped structure we see in the sea level contours around the inland waterway.

We can also look at the temporal structure in the Japanese sea level data. Here are the plots of the first three temporal eigenfunctions. Unfortunately, you will have to ignore the data previous to 1950 since there were too few stations during this period to give statistically accurate results. The data for the 1st eigenfunction after 1950 shows a generally increasing trend. Associated with this curve, however, is a fair amount of variability. It turns out that these fluctuations in the temporal data can be related to two phenomena: the Southern Oscillation, and meanders in the Kuroshio Current, a western intensified boundary current similar to the Gulf Stream but in the North

Pacific.

Lastly, I want to show you some data from the Fenno-Scandia region, an area that we know has been dominated by isostatic readjustment. Here is a contour plot of the relative movement of the land in mm per year, reconstructed from the eigenfunction analysis. Norway, Sweden, Denmark, and Finland are in the upper right, Great Britain in the lower left, and the European Mainland in the lower right. The contours show two concentric regions: one over Scandinavia that decreases outward, from the high positive values over the center to lower positive values on the outer edges; and the other over Great Britain that increases outward, from high negative values in the center to lower negative values, zero, and positive values on the outer edges. These results correlate quite well with what we know about glacial rebound of the Scandinavian region and the relaxation of the forebilge over Great Britain that has occured since the retreat of the continental glaciers.

In conclusion, we know that there is a great deal of regional variability in sea level. So if we take sea level measurements from around the world, it will be difficult to obtain a meaningful estimate of eustatic sea level rise. It is obvious from the data I have just shown you that averaging the sea level data from all the regions of the world together to obtain a global rate of sea level rise would lead to a misleading result. Similarly, in regions where there is very sparse tide gauge coverage, such as in the Southern Hemisphere, using one or two tide gauges to determine the sea level signal for an entire region may be misleading because of the great variability within each region.

Therfore, our approach has been to analyze the world, region by region, and try to pull out the isostatic signal, the tectonic signal, and the oceanographic signal to come up with a better estimate of the global sea level change. Then we can watch sea level on a yearly basis, and see if the statistics change, and determine how sea level is responding to global warming due to the greenhouse effect.

DR. FESSENDEN: Thank you very much, Barbara.

Our next speaker is Dr. Suzette May from the Coastal Engineering Research Center at WES, and her presentation is entitled Influence of Sea Level Rise on Inlet Dominated Barrier Island Systems.

INFLUENCE OF SEA LEVEL RISE ON INLET DOMINATED BARRIER ISLAND SYSTEMS

DR. MAY: Good afternoon. At the Coastal Engineering Research Center, I am working with a work unit entitled Barrier Island Sedimendation Studies. These studies are directed towards the objectives of developing models of barrier island development and geomorphic change in both long-term and short-term time scales; long term being defined as geologic time scales, and short term being those which are applied for engineering planning purposes.

To this end, we have been involved over the past three years in a major field study looking at stratigraphic and sedimentologic evidence of geomorphic development. One of the objectives is to develop postulated sea level curves for the

Atlantic Coast of the U.S. This report is a summary of the culminationof these efforts.

We have been looking at areas in New Jersey and the Virginia barrier islands, and as was pointed out this morning, the New England area has quite a different setting geologically and a different setof geologic controls. Nevertheless, the global estimates, and I use the term advisedly, of sea level rise that can be achieved from these types of sedimentological studies have applications beyond the New Jersey region.

The major conclusions that came from this study are that generally, along the East Coast the sedimentology and stratigraphy imply that there has been a transition from higher to lower energy back barrier environments, that is, an infilling of back barrier environment -- that sediment is introduced into the back barrier environment through inlets -- overwash plays a minor role in the development of these systems -- that in New Jersey and Virginia respectively the rates of sea level rise over the past 5000 years have been 2.0 and 1.5 millimeters per year. And lastly that the barrier island retreat problem that we see along the mid-Atlantic coast is, in the long term, caused by the combined effects of sea level rise and sediment deficit. The rollover model of barrier development that has often been postulated in these areas is not being supported by the work that we have done.

In the areas that we studied, we looked at the entire system from the ocean side through the profile of the barrier island across to the back barrier regions and into the back barrier marshes to the Pleistocene uplands. Our objectives were to delineate the depositional environments, delineate and identify the general stratigraphy of the area, identify sources and sinks of sediment, from the first three to determine a seriesof sea level curves for these areas, and to postulate future sedimentation trends along the mid-Atlantic coast.

Again, the areas that we looked at were the southern barrier islands in New Jersey from Atlantic City south to Cape May. A series of six transects were laid out across these barrier islands. This is an interesting area in that we have a few relatively undeveloped barrier islands with very wide marshes, and a large degree of sedimentation and infilling in these marshes. However, there are also areas that are very highly developed and have earned in certain circles the notoriety of being the type location for the "New Jerseyization" problem. We see similar stratigraphy in these areas, although the response problems are quite different.

In the Virginia barrier islands, we looked at an area from Assawoman Island, south of Assateague Island, transect A, down to Smith Island at transect F-F' prime. These areas are undeveloped and are managed by the Nature Conservancy. They are characterized by a very thin veneer of sand overlaying marsh deposits which can be seen outcropping along the ocean shorelines of the islands. We also see a lot of back barrier infilling through time as sell as wider lagoonal areas than we saw behind the New Jersey barriers, and some fairly competent tidal channels.

The data base for the study includes a series of vibracores four to ten meters in depth, radio carbon dates from the organic material, in the cores, and a study of the microfossils and the heavy minerals, primarily ostracode

identification. We also looked at historical maps and charts for a view of the trends of shoreline development.

As part of this project we modified existing vibracoring instruments to achieve a light weight protable coring device that could be used by a 2-person field team in the shallow water back barrier systems.

This slide shows the New Jersey barrier system. We see several depositional environments that can be characterized through time for both the New Jersey and Virginia areas. These are: the barrier island itself, the back barrier marshes, wider lagoons, some tidal flat areas; the larger tidal channels, and the small tidal tributary channels. Throughout most of the study area there is a larger open water lagoon than this particular slide would indicate. Whether the back barrier area is marsh filled or open water, we find that it is typically backed by a Pleistocene upland that ranges two to three meters in elevation above the open marsh areas. This slide shows the Virginia barrier islands. and again we see the same types of transition through the back barrier and tidal flats to the marshes upland.

The stratigraphic record shown in this slide is a composite drawn from the cores taken throughout both the Virginia and the New Jersey study areas. We can see from the pre-Holocene through the Holocene a general transition from a lagoonal and estuarine or fluvial deposit through the brackish salt marsh, sand flats, to the mixed mudflat which is a higher energy lagoon, a muddy tidal flat, and the fringing marsh and shore deposits. We find that these series repeat themselves in a cyclical fashion.

We have been able to document back barrier infilling through historical maps and charts. These are the Rainbow Islands in New Jersey. The areas that are shown in the larger stipple were the Rainbor Islands in about 1830. We can see that there has been recent shoaling and coalescing of these islands as this back barrier region fills.

We see this same trend in Virginia. In this particular case this slide shows an USGS topographic sheet of the southern end of the Virginia barrier islands. This was mapped in 1946 and you can see extensive bay and lagoonal areas, which by the 1969 update had coalesced to major infilled marsh areas. So we see that we can document this general infilling in the back barrier region with historical data. The infilling must be promoted by some process, such as a readily available sediment source and the effects of sea level rise.

The New Jersey problem is modified and exacerbated by some of the engineering structures y-hat do not permit sediment to flow into the back barrier regions through an overwash type of process. The Virginia barrier islands have a very thin veneer of sand over cohesive organic rich sediments. Major sand sources are not readily available. However, we find considerable infilling and coalescing strengthened by marsh development in thse back barrier regions.

These are three possible sources of the sediments in the area -- overwash, upland runoff, and inlets. We were looking for evidence of what the dominant sediment sources would be in the context of continuing sea level rise. The first possible source, overwash, was documented by numerous washover flats, particularly in the Virginia barrier island area. However, in the

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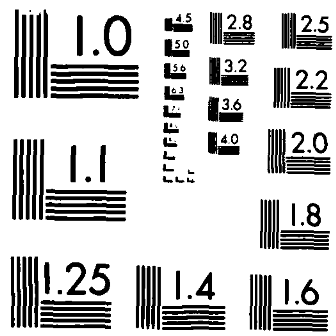
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stratigraphic column we found very little evidence of any significant overwash deposits in the back barrier and, indeed, in any areas beyond the active foreshore. Therefore, we could not make a statement that overwash contributed significantly towards the development and the maintenance of these systems.

The second possible source, the uplands, were represented as a major stratigraphic constituent in the core strata defined as Early Holocene. We find that as recently as 5000 years before present, we can identify upland sediments, but that they are becoming, through time, increasingly rare in the stratigraphic column. This leaves inlets as our majkor source of infilling. This slide shows the large volume of sediment stored in the flood tidal shoals which is redistributed through the tidal channels into the back barrier areas, and becomes the substrate for marsh growth.

Looking at the stratigraphic evidence, we find documentation of sea level trends through both New Jersey and Virginia. We obtained radio carbon dates from basal peats, articulated shells, and some of the modern marsh sediments. These dates are useful in determining the relative sea level position through time.

Developing sea level curves from the dated material, we found that we had two distinct curves. In this slide, the one in red is based on the information shown as squares from the New Jersey data; the green curve is based on data from Virginia. The dates derived from this data set are combined with data derived by other researchers; for instance, we compare our data with those illustrated by the open circles, representing work by Newman and Munsart.

On an average, in New Jersey we have a rate of sea level rise of about 2 millimeters per year over the past 6000 years. The period from 6000 years before present to about 2200 years before present was marked by very rapid rise. There is an inflexion point where the rate slowed at 2200 years before present. Within the past 500 years there is, again, a more rapid rise in the sea level.

In Virginia we found that the average rate of sea level rise was somewhat lower,about 1.5 millimeters per year over the same past 6000 year period. These data are consistent with those developed by other investigators along the mid-Atlantic coast. Similar to the New Jersey data, at about 2200 years before present, there is another small inflexion point and the curve's slope shifts to somewhat slower rates of sea level rise.

We have seen very definitely that the sea level rise rate is higher in New Jersey than in Virginia. Very possibly this is due to recent relative subsidence of the coastal areas with shifting and readjustment of the edge of the coastal plain after changes from unloading from the ice sheets.

If you look at tide gauge data, you see somewhat higher rates of change for sea level rise. This particular one is the Atlantic City, New Jersey tide gauge, and we find that during the past hundred years, we see much higher rates of sea level change. Gauge data shows rates of sea level rise over the past eight years of about 4.5 millimeters per year in New Jersey, and rates of 3.6 to 2 millimeters per year at Hampton Roads, Virginia.

These data would indicate that sea level rise rates

are higher now than they have been at any time in the past 5000 years.

You may compare our data -- again, in this slide the red represents the New Jersey data and the green is the Virginia data -- with other studies in the mid-Atlantic region. The dash line shows data from Belknap and Kraft, the dotted and dashed is Sheppard, and the last Stuiver and Daddario. The rates compare favorably in that they are in the range of 1.3 to 2 millimeters per year over a 5000 year period.

This slide shows the data for sea level curves developed in Delaware. Our data for Virginia shows a slightly lesser rate of rise, and the data for New Jersey documents a slightly higher rate of rise. One finds that there is an overall trend toward a more rapid sea level rate of rise as one moves north along the mid-Atlantic coast.

Now, this is a sea level curve developed from data in South Carolina by Colquhoun and others, and it shows the types of fluctuations that one finds in sea level data over 500-year intervals. We show this slide to make the point about one of the problems that we have in using sea level data which was discussed earlier today, that often the seasonal or short-term fluctuations can be much greater than the overall trend. This is a problem to be considered in short-term, 50 to a hundred year planning decisions.

We concur with the findings of Cinguemani and others who suggest that there is a difficulty discerning sea level fluctuations north of the Cape Fear arch due to the relative magnitudes of the trend and the noise in the data.

In summary, through this project we generalized the stratigraphic cross section in the mid-Atlantic area, and developed a conceptual model to incorporate sea level change and sedimentation through inlet processes as mechanisms for barrier island movement and development. The cross section we find is comprised of the barrier beach and the Pleistocene upland, with a fining upward sequence from sand flats to muddy tidal flats to the modern marsh which caps the sequences. This is deposited during the Holocene when rates of sea level rise were varied but continuously increasing.

We also see a scenario of rapid sea level rise and barrier island retreat with very high energy back barrier sedimentation up to about 5000 years before present. This is followed by a period of slower sea level rise and consequently some barrier retreat with continuous narrowing of the lagoons between about 5000 and 2200 years before present.

Since 2200 years before present, we've seen a slower sea level rise and a change from subaqueous to intertidal sedimentation in the back barrier region. Lately we've seen more rapid sea level rise, and for the past 500 years we've seen a continuous narrowing of the lagoons through both barrier island retreat and infilling. In turn, the width of the tidal inlets has been decreasing through this area as deduced from historical map sheets. This is assisting in creating a lower energy back barrier environment which facilitates marsh development and marsh growth.

In conclusion, we've seen that the sedimentology, stratigraphy and the microfauna imply a transition from higher to lower energy back barrier systems over the past 500 years.

More importantly we see that sediment is introduced into this environment through tidal inlets. We find very little evidence that overwash is playing a major role in the geomorphic development of these barrier islands.

We find that the New Jersey and Virginia sea level rise rates are 2.0 and 1.5 millimeters per year respectively over the past 5000 years, although over the past 500 years we see much higher rates of sea level rise in these areas.

And finally, we can make the statement that the barrier island retreat problem that we see along the mid-Atlantic coast is caused primarily by a combination of the long-term sea level rise and a sediment deficit in that region. Thank you very much.

DR. FESSENDEN: Thank you, Suzette.

Our final speaker for this part of the program is Dr. Joseph Kelly, marine geologist with the Maine Geological Survey, who will discuss The Impact of Local Sea Level Rise In or On Maine.

THE IMPACT OF LOCAL SEA LEVEL RISE IN OR ON MAINE

DR. KELLEY: Thank you. It was probably inappropriate of me to use the word "local" in conjunction with the coast of Maine. Although it only 250 miles from New Hampshire to the Canadian border, the tidally influenced shoreline of Maine is more than 3478 miles long, making it one of the longest shorelines in the United States.

Not only is it a very long coastline, it is one which has been very poorly studied, in fact not studied very much at all. I wrote a paper a couple of years ago about sediment transport in Delaware Bay and restricted myself to citing about 50 pertinent publications on the geology of that bay. I recently completed a paper on the geology of Casco Bay along with Dan Belnap and Craig Shipp of the University of Maine and found myself citing for a geological references only two other geological papers written by Peter Larsen, an acknowledged biologist. So it is a long coastline. It is one which has not been very well studied, certainly not in any detail. And as others have noted, it isn't a coastline on which we can look to other states and previous work elsewhere to tell us very much. That is so say, Maine has experienced an ice age, the better studied coastal plain estuaries to the south have not, so we've got a very different sort of situation.

To get acquainted with the coast, when I arrived at the Maine Geological Survey a couple of years ago, I went out and conducted a census of sort by using sources seen here, a number of maps and charts, and in several hundred location, 340 to be exact, along the coast I made observations from these maps and charts of the elevation of land behind the supertidal areas, the depth offshore, the orientation of the coast, and quite a number of other features. I ended up with a data matrix of about 340 samples by 17 variables.

When I subjected that to a Q-mode factor analysis, which is a way of reducing the data to a simple structure, I was able to decide that the coast of Maine could easily be described by three end member components; that is, typical profiles which

best illustrate the features of our coast -- a mudflat component or profile seen drawn to scale here commonly seen on almost half of the coast of Maine; marshes represent a very important part of the state in terms of the area of tidally influenced shoreline that they occupy with ledge or bedrock being a less important factor. Beaches do not occupy, obviously do not occupy large amounts of the tidally influenced shoreline of Maine.

When these profiles are arranged in a geographical sense, one can see an ideal Maine estuary, seen here, with an outer zone comprised of largely bedrock in red with some coarse flats or some gravel beaches, and inner or central estuarine region or embayment with rapidly eroding bluffs feeding sediment to mudflats which accrete at a variable rate as has been shown by Franz Anderson and some others from the University of New Hampshire. Marshes in this area tend to be rapidly retreating, if they exist at all. Finally, a landward area where the turbidity maximum of estuaries is seen, where estuaries are experiencing the growth of salt marshes propagating across mudflats and relatively little retreat of bluffs.

Regional variation of this model can be seen here; that is to say, all of the embayments on the Maine coast are not the same. The southern part of the state, as has been noted for a long time, is comprised of a large number of rocky headlands with long sandy beaches and salt marshes behind them. The central, south central coastal area, west central coastal area, has a large number of long narrow estuaries controlled with respect to their shape by bedrock; an east central coastal area, which is where we are right now, right here, have broad estuaries with an abundance of rounded granitic sorts of islands; finally, a northern portion of our coast with a long straight cliff shoreline with Cobscook Bay being an unique feature built into that.

While there is considerable variation not only in the large scale structure but in the kinds of environment one finds across this coastline, proceeding just very quickly from the southwest, that is, near the New Hampshire border, one finds that the coast, the tidally influenced shoreline is dominated by marsh environments with subordinate mudflats; the south central area near Portland has dominant mudflats with subordinate marsh environments; the north central area where we are, predominantly mudflats with subordinate ledge and beach environments, mostly gravel beaches I should point out; and finally the most northeastern location near the Canadian border, predominantly mudflats, have large tidal range there with quite a large amount of the ledge exposed in the intertidal zone.

I had objected at one point in reviewing the Bay of Fundy paper edited by Peter Larson and others to the amount of acreage of Maine's shoreline that would be drowned by a 15 centimeter higher high tide. It was based partly on my consideration of the methodology employed by the author who concluded we'd lose about 4000 acres of land to the rising water. I consider just salt marsh alone, which measure approximately 17,000 acres of land in Maine, as being prime candidates to be influenced by higher high tides, and then an additional amount of land would be drowned that is not marshland.

I think a better way to approach this problem then would have been to stratify one's observations both along the

coast and perpendicular to the coastline and then to further subdivide observations into different environments.

This is a subject matter for a longer talk. I won't go into it here. The relief across the coastal zone is the change in elevation from the upland to offshore. As one proceeds from the southwest, one finds very low relief area, about 24 feet, because it is dominated by low relief salt marshes. As one proceeds to the northeast 69 feet of relief on the average across the coast dominated by a lot of beaches, of coarse flats and ledge environments. So the coast is very different from north to south as well from the sea to the land. Not easily generalized on the basis of one detailed study of one bay, of which we don't even have that.

That's just a brief overview of the state's geography. I have some preprints available out in the poster session area that goes into that quite a bit more detail.

Regarding the geological history of Maine, I'd just like to briefly talk about the late Quarternary history. Obviously we begin about 18,000 years ago with ice having glaciated our landscape, ending down here near Cape Cod. The ice retreated in Maine. I should point out it left a large number of moraines along the coast. One seen right here, Sprague Neck in Machias Bay has been the subject matter of a Ph.D. thesis by Craig Shipp. These moraines have had a profound influence on the evolution of our coastline as sea level has transgressed across them.

But as the ice was leaving those moraines; here's a cross section through one, not that one but one nearby, one finds not simply till but a number of stratified materials suggesting that the presence of water was nearby. Dr. Hal Borns at the University of Maine has been studying this sort of phenomenon for quite some time, and it's a result of subsidence of the earth crust due to the weight of the ice. The weight of the ice pushes down the crust, and so as the ice was retreating, the ocean, though lower than it is at present, there was less water present in the world's oceans, the crust was sufficiently depressed to flood the landscape.

Here is an illustration of Dan Belnap's drawn from the new state's official geological map by Thompson and Borns showing the extent of drowning of the Maine coast between about 13 and 11,500 years ago. Some areas were left as islands. Marking the marine limit or the upper most part of the drowned section are these yellow areas which represent deltas fed by erosion of coastal materials as well as an influx of glacial melt- water. Here we see a rather extensive delta going out into what was then at one time the ocean. It's very nice to be a state geologist, you can command people to burn the land so you can take very nice aerial photographs. Actually these are blueberry barrens today.

After the ice reached it's maximum, it began to fall again and it's generally stated in Maine that there are very few indications of the falling sea level, very few shorelines, and so we infer that the fall of the shoreline across our landscape was rapid. There are a number of notable ones seen very visibly right here. I suspect actually that there are more than a few. We really have no data at all on the rate at which the sea fell across our shoreline.

I was recently on a field trip. I had occasion to note this, the large drumlin in southern Maine with some evidence that the sea fell sufficiently slowly that it caused considerable redistribution of previously deposited material. This was about a 150 foot high section of glacial till. As the ocean fell across it, one can imagine that its eastern side was exposed to the full impact of the waves. I certainly would have expected to find shorelines cut into it. If one looks on a topograhic map, one sees that there is a broad platform, shallow platform to the east, and if one examines cuts in that platform, one can see glacial till down here with erosional contact with a stratified material and on closer examination, the stratified material contains burrows of an animal. I'm not a biologist. I don't know what sort of the organism it was. But clearly as the ocean fell across the coast of Maine, there was a considerable redistribution of material. Probably beaches existed, animals of various sorts no doubt flourished.

Here is a graph Detmar Schnitner published a number of years ago showing in graphical form the changes of land and sea in Maine. Here showing the general eustatic rise of sea level. Also showing the behavior of the crust of Maine, here submerged, weighted down by ice, rising very rapidly after the ice was lifted off, the load was removed, reaching a point of maximum emergence, that is, maximum distance between the ocean and land surface, putting a shoreline out to about 65 meters below present sea level at sometime around, well, there are no numbers to hang this curve on but probably around 9000 or so year ago. So water drowned our coast, fell back across it to a present depth of negative 65 meters and has subsequently risen.

Here is just a slide showing the stratigraphy which has resulted from that: polished and striated bedrock not well seen here, glacial till at the base of our Quaternary section, the Presumpscot formation, that is the marine clay deposited by the drowning which followed the removal of the ice. But the land even as this material was being deposited in fairly deep water was being uplifted. Finally, the land came through the coastal zone. Again, we see the reworked material, probably a mudflat or subtidal deposit here, and finally fresh water peat deposits on the surface. Today, of course, this entire coastline is again drowning.

Just a closeup picture showing the unconformity here at the surface which was caused by erosion of this material by the ocean falling across this recently emerged sea floor. As geologists have long known, most of the geological record is probably not present; that is, most of the time represented by this geological section is not shown here. There was probably considerable erosion of material as the ocean fell across this area, although I have no measures of how much erosion, just a nice drop stone here in the deep water facies of Presumpscot.

That surface that I showed you there caused by the falling of the ocean across the land is also manifested in other ways. Here is a typical Maine area with a ravine cut into the Presumpscot formation, which is the marine clay. One can image the ocean sea floor being up lifted and exposed to subaerial weathering processes as a quick clay of sorts. It was subject to mass movements, gullies formed, and I suspect that vast quantities

of material were flushed out of ravines of this sort and have disappeared from our landscape due to the erosion during the subaerial period.

Just an aerial photo of the Maine Audubon Society's area on the Presumpscot River in Maine, type locality of the Presumpscot formation, the marine clay I've discussed. Here we see they are in a fairly flat area as are some areas over in here which mark the undisturbed form of seaflow. Here we see ravines cut into this Presumpscot formation, this marine clay during the emergence. Here we see a fairly stepped, chaotic area. A number of similar areas are seen over here. I suspect these represent mass movements. Paleolandslides of different sorts, very, very common in the Portland area. So there was probably an export of a fairly large quantity of material from topograhic high areas to low areas during the period of emergence of the landscape. This is a continuing process as we shall see at the present time.

What happened when the ocean fell out to a present depth of negative 65 meters? Some seismic profiles collected by myself, Dan Belnap and Craig Shipp from the University of Maine last year. This is the Portland area. These are just some of the track lines.

To summarize, what we observed is a large area of generally exposed bedrock, seen here in red, in the outer part of this estuary and many other embayments in Maine, and a central or an inner area comprised of a large amount, filled with a thick quantity of sediments, certainly greater than a meter. There is some glacial till seen here in purple.

The ocean fell out to this area out here, probably about 8500 or 9000 years ago, something like that; and then the land was still rising up out of the ocean and sea level continued to rise; and so I suspect there was a relatively slow rate of sea level rise which resulted in consumption of previous deposited materials from this area. So materials were completely, almost completely, removed from that area because of the relatively slow rate of sea level rise.

I'll show you this seismic track right here. One goes from the land to the sea here. In red one sees bedrock, maroon is glacial till, and this blue material is the marine clay. Here it's very much removed. One sees a large amount of bedrock exposed on the sea floor. And where the marine clay does exist, it tends to be very hard near the surface, suggesting an erosional lag surface and a seaward dipping slope is seen on all of the surfaces here suggesting transgression by the ocean in this direction. Considerable channeling within the marine clay suggests that the depths, the ultimate depth to which the ocean fell was possibly more than 65 meters. This was simply as far offshore as we went on that particular day.

A couple of tracks I'll point out. The inner bay is quite distinct. Sea level rose slowly out here and consumed a lot of the material. It probably rose fairly quickly in the inner bay, I'll show you this line first and then this other line here.

One sees here again bedrock in red, glacial till is purple, the marine clay is seen in blue, and modern or holocene sediment is gray with natural gas deposits shown as green. What we see here are valleys cut into the Presumpscot formation into this marine clay when it was emergent. As sea level has

transgressed or crossed this, highly productive estuaries have migrated up across what is now open water and left a large amount of organic matter which has become natural gas. It is capped by a modern deposit which is itself today being subject to reworking or redistribution by, in this instance tidal processes, this channel here. One notices a number of interesting reflectors or layers within the Holocene sediment moving it up toward the land. One can look at the land in this area and have a feeling for what those are. Here are bluffs of till eroding as a large part of this coast is. As these bluffs erode, they shed boulders and other material into the ocean. Here's a layer of coarse grained material that will probably form a future reflector. It will be covered by quiet muds waiting the next major storm or whatever event it takes to cause more erosion. So we see that the stratigraphic record is fairly simply interpreted by looking nearby at what is happening to the margins of our shoreline today.

Here's the other profile going from land near the mouth of the Royal River in Portland to a point off shore. Again, the red is bedrock, completely covered, I should note here, almost completely covered. The section is much more complete because sea level is rising more quickly across this surface as opposed to the slower more consuming rise across the outer part of the bay.

I would point out that the Presumpscot Formation there is no modern sediment here. This was once inferred to be the delta of the Royal River. No modern sediment at all. It's Pleistocene material at the surface. Heavy metals from this area I would expect to be very low. I said that to Peter Larson who did a study in that area because it's basically ice age clays with no modern materials around.

I call your attention to this gray area of Holocene sediment over here. One of the only sandy areas we found appears to have been a drowned tombolo or beach type feature. We've not cored it but it's a sandy area. It has a geometry similar to a beach, and it connects to rocky islands, probably fairly analogous to this now dying tombolo that used to connect the two Chebeague Islands in Casco Bay, drowned due to a lack of sufficient sediment and sea level rising across this area: not enough sediment to maintain itself in the face of the rising sea level, and so probably drowned in place.

Well, we move up toward the present. Sea level is continuing to rise in Maine. This is data from Stacy Hicks, 1983. These are -- I should apologize, I suppose. These are least squares fits, simple regression lines that simply minimize the sum of the squares of the differences between the observed and the predicted observations on the basis of these linear equations. I don't have any way of knowing what the true shape of the data is. It's very complicated looking, so I've taken these lines which are significant. They have significant correlation coefficients as they best fit to the observed data. I'll simply note that these lines are not equivalent; that is, the three areas are not experiencing identical rises of sea level with Eastport near the Canadian border experiencing the steepest rate of modern sea level rise as recorded in tide gauges. One explanation for why this may be happening as seen in this illustration -- of which I have a reprint including it, it will be published in geology next month -- worked principally in this instance by Dave

Tyler, a geodesist at the University of Maine, showing the rate of seeking of the land from 1 to 9 millimeters per year based on repeated releveling of the first order level network in the state, or else a large number of earthquakes in this area associated with that. From that one one might infer that hydroisostatic loading or the weight of the water in this region is causing the sinking of the land and a reactivaion of earthquakes or faults that were originally formed quite some time ago.

Some of the things, the activities that have resulted from this sea level rise in this area are erosion of bluffs seen in 1881 here in the formation of spits; that is, the older material as in times past is being redistributed by the modern rise of the ocean. In this instance we gain land by forming beaches. Other areas homeowners don't like to see their property redistributed are different. There will be no beaches forming from Great Hill in Kennebunk because it is fairly adequately riprapped today.

Another area of sediment redistribution which, as I'm going to conclude, is the predominant geological process which accompanies sea level rise in our area results in problems. Down here in Wells Maine, as I'm sure the Army knows, the sand always seems to accumulate where we like to have a harbor.

Other areas, probably a point I should make is that a number of environments can't keep pace with sea level rise. Here we see salt marshes which must maintain themselves at the level of the ocean. If sea level rises more rapidly than mud is supplied to the surface. They erode. This particular marsh has eroded at a half a meter per year since the 1960's. Certainly the addition of a component of a higher high tide to this area would result in still more significant retreat of the marshes. There is a poster session presented here by Dr. George Jacobson and Heather Almquist that discusses some of the implications of a higher high tide on Maine's salt marshes.

When the marshes disappear, bluffs become exposed to waves, and themselves begin to retreat. This is a very common scene. This is Machias Bay. Retreat seen all along the entire coastline in most of the State of Maine. Occasionally the retreat is catastrophic. Here is a large slump that occurred a few hundred meters from here in 1973. If you go out, however, to examine it today, we have a nice picture of this in our poster session, we're right over here today. You'll see there is nothing left. There is a lot of turbidity though. So the memory of the sediment redistribution from this landslide is enhanced turbidity, accumulation of sediment on mudflats.

A few other problems. There is also a poster session presented by Andy Tolman from the Maine Geological Survey talking about the impact of rising water levels on groundwater, particularly on some of the long peninsulas in the central part of the coast which have water basically on all sides except one and are very susceptible to salt water intrusion with rising water levels.

The last slide is to simply say there is also a human element. This was a harbor in the 1750s in which ships were constructed. The first colonists to this area, however, cut down the trees along the bank to make the ships, as has been documented

by Dr. David Smith at the University of Maine, a historian, the erosion of materials along the bluff very quickly led to the filling of the harbors and the end of that activity as an occupation for people in the area. Trees subsequently regrew over the landscape, preventing subsequent rapid erosion of the land, preventing subsequent influx of sediment to this area. Dams were built on the rivers, and now you see the marshes retreating. They are sitting on top of the old working platform of a dock. Sea level has drowned it. It's still grows upward a little bit, but it's retreating because it's out of sedimentological equilibrium. That is to say, sea level is rising far more rapidly than this marsh requires for sediment.

So in conclusion I would say that the predominant geological process in Maine accompanying all of the changes of sea level, both those in the earlier as well as the later part of the Quarternary, the predominant geological process has been sediment redistribution, erosion here, accumulation there. Thank you.

DR. FESSENDEN: Thank you, Joe.

We will take a short break. Perhaps for those of you who came in a couple of minutes late, I'd like to repeat a couple of announcements. The evening session will begin at 7:30 this evening rather than as original mentioned at 8 o'clock. So the evening session begins at 7:30. And I would just like to repeat my plea earlier, the speakers to please send to Tom Bruha at the Army Corps of Engineers, Waltham, Massachusetts, a copy of your talk so that the technical terms and so forth can be included in the transcript.

All right, we shall take a short break, maybe about 10 minutes and then we'll come back here for the discussion.

(A recess was taken.)

DR. FESSENDEN: I've been asked to remind everyone that reservations are necessary for dinner, and again keeping in mind the rather tight time schedule that we are all faced with, I would suggest that if you have not already made reservations for dinner that you do so after this discussion period.

We have joining us for the discussion period Barbara Braatz, Suzette May and Joe Kelley, and also as I said Duncan Fitzgerald joining us for this discussion period on the subjects which we have recently been discussing. So without further ado, I'll invite any questions or comments from the audience.

DR. GREENBERG: David Greenberg, Bedford Institute of Oceanography. I'd just like to bring to some people's attention a study that Dave Scott, a geologist at Dalhousie University and myself have completed, is now published in the Canadian Journal of Earth Sciences, and if I could give a 30-second summary of what it is. Dave dates marsh form inifra and considers them to be a marker of high tide at whatever that date was.

The problem in the Bay of Fundy and Gulf of Maine system is that the high tide alone marker is not going to give you a measure of how mean sea level has evolved. So Dave wanted to separate the two effects. What we did was we ran the same model that I was talking about earlier, but changed the depths and tried to figure out how the tide would change with changing sea level.

There are a whole bunch of rather complicated results that come out, depending on resonant effects, friction

effects and all this. But one rather overall result came out that maybe override a lot of the gross assumptions made in the modeling, and that is that the offshore depths, the deoths eastward of a line from Cape Cod to Yarmouth seem to determine whether the area is macrotidal or microtidal.

The shallower unique Georges Bank northeast channel area, the less tide you have. The ratio does not appear to be the one-for-one change tidal amplitude sea level that some people have talked to in the past, notable Grant in the upper Bay of Fundy. But a one meter decrease in depths over Georges Bank seems to correspondence to a 1 and a half to 2 percent decrease in tide in the inner Gulf of Maine. And I think that's the main result we came out with. So I'll leave that with you. And as I say, the study is available in the Canadian Journal of Fisheries and Aquatic Sciences -- the Canadian Journal of Earth Sciences, sorry.

DR. FESSENDEN: Joe.

DR. KELLEY: I'd just like to comment a little bit about that. I had read that work. I enjoyed that paper. When we were looking at the rate of subsidence of that part of Maine nearest Campobello Island right there near the Bay of Fundy, it struck me -- I'm not a geophysicist or a geodesist, but it struck me that the subsidence in the seismicity there might be related to the weight of the water that has increasingly been more and more present in that area due to the increase tide as well as to the rising level of the ocean. As I said, I don't really know that. It's speculative but it struck me as something that might be investigated by a group planning to put still more water up there for a longer period of time in conjunction with the Fundy tidal power project.

DR. FESSENDEN: Anybody else wish to raise a question or make a comment or address the issue.

DR. BELKNAP: Dan Belnap, University of Maine. This is a very simple question for Barbara Braatz. Where did you get the information that the ice cap is accumulating instead of melting?

MS. BRAATZ: I was just asked that question, and I'm afraid I don't have any references. That's from word of mouth from Dave and he left before I had a chance to ask him.

DR. BELKNAP: I think you'd better check on that.

MS. BRAATZ: Okay.

DR. KELLEY: Just to add to that. As well Dan Belnap knows, the University of Maine, George Denton and Terry Hughes have studied the South Pole quite a bit, and quite the contrary. Their published opinions in Science, quite a prestigious journal, is that not only is the ice cap melting, it conceivably could melt rather rapidly. The west Antarctic sheet in particular, which today is marine based, is resulting in an extreme rise in sea level within the next hundred years.

DR. FINK: Ken Fink, University of Maine. I can't resist having a microphone so close to me. I'll address my question to Ms. Braatz again. I noticed in your rather sophisticated techniques that you used that you didn't get too dissimilar values in terms of sea level rise from what's been done by Stacy Hicks and others in looking at tide gauge data. Did you find any big discrepencies, get new information, new rates, or did that pretty well verify what people have known about sea level

rates?

MS. BRAATZ: As far as global rates or just region signal?

DR. FINK: No, just local sea level rise. You showed along the East Coast of the U.S. as from your spatial determining.

MS. BRAATZ: Our estimates don't vary in a regional sense all that much. What we're trying to do is come up with estimates that will enable us to quantify what the various signals are, what the isostatic signal is. What the tectonic signal is. So many of those other studies we're trying to come up with a global average, and that's not the purpose of our study. But you're right, on a regional sense the estimates don't vary very much. But they wouldn't. They're from the same data source.

DR. FESSENDEN: Any other questions or comments?

DR. BELKNAP: I don't rant to keep picking on Barbara Braatz. Your data showed a longshore change in the rate of sea level rise from Cedar Key right up through Eastport. In a paper in '77, Chris Kraft and I suggested that hydroisostatic loading is in effect on sea level rise in a local sense. And there seemed to be a fairly good correlation between the width of the shelf and depth of the water, especially the Gulf of Maine with that kind of trend that you saw. Do you think that hydroisostatic loading could have something to do with this?

MS. BRAATZ: I think there could be. Unfortunately there seem to be -- there doesn't seem to be any quantative way at present to really come up with an answer to your question. I'm not sure depth-to-shelf break is as simple as that. I think there are probably a lot of variables involved, and it's not going to be directly related to sea level changes. There are other variability that you have to take into account like sediment loading, like the tectonic structure of the East Coast. Because the weight of the water is going to have a different effect along different sections of the coastline because of the structure underneath. Does that answer your question.

DR. JACOBSON: I'm George Jacobson from the University of Maine. I really have a comment. I would like to just take this opportunity following Joe Kelley's mention of the relative importance of salt marshes along the coast of Maine as a proportion of the total coastal area and linear distance to emphasize what I believe are very significant economic and environment or ecological implications for effects of changing tidal amplitudes on salt marshes. Biologist tend to recognize these things, and I suspect many people in this room do, but I'll run through a brief list anyway.

Economically salt marshes are important because they produce a high flow of nutrients into local mudflats, and therefore are important to the shellfish populations in there. And also nutrients are going into the open ocean and are important for productivity of vertebrate and invertebrate fish there. They also serve as a natural filtering system for heavy metals and organic waste that pass from the upland towards the ocean, and have clearly are important as wildlife habitats for resident and migratory waterfowl invertebrates that form the basis for the fishery food chain. And also actually the marshes themselves serve as nurseries for the young fish populations living in the

ocean. And for these and other reasons, it's quite clear that if we change the nature, either the nature or the extent of salt marsh in the state that we will be having some important effects on economically and ecologically important features.

Now, we have in the last couple of years initiated some of the first studies of Maine salt marshes that have ever been done really, and Heather Almquist working with me and with Joe Kelley of the State Geological Survey have been evaluating the modern vegetation and the relationship of the vegetation to the variations in physical and chemical parameters in the marshes, and along with Joe Kelley and Dan Belnap, who are getting a start at understanding the historical changes in the marshes for the last few thousands of years.

We've discovered in our preliminary work, some of which is mentioned in a poster session upstairs, that Maine salt marshes are extremely diverse, one from another. Much more so than the marshes that exist on the Atlantic coast say from Rhode Island south. Most of those marshes tend to be quite uniform and have similar zonations, similar species present. We find in Maine quite the contrary that the marshes vary considerably one from another. And we're just beginning now to understands why. Some of the complicating factors, we believe, are the great difference in tidal amplitude from one part of the state to another. And we're trying to understand that. We have some gauged salt marshes from which we've done our vegetation work. We have the differential crustal warping which is changing local sea level quite rapidly in some parts of the state, and we think that's another component to the diversity, and of course we have differences in cultural disturbance and sediment loading to different parts of the state.

All these things together create an interesting and challenging problem for us. But it's one I think we really can't ignore. I don't mean to say that beaches and the movement of sand are not important because they are, but I think given the relative proportions of these things in the state and the significance of them to probably Maine's economy, they're really an aspect of the whole tidal power issue that we can't ignore. I notice that in the original report that was done for the State Planning Office that salt marshes almost went without mention.

DR. FESSENDEN: Any other comments or questions?

DR. FINK: I have another one for Joe. Joe, the graph you showed in terms of the subsidence rate based on releveling surveys for Eastport showed a rate on the order of 8 to 9 millimeters per year. And the sea level, the tide gauge data shows something on the order of 3 to 4 millimeters per year. Could you resolve that discrepancy for us.

DR. KELLEY: I wish I could. Different timeframes. You pick different times to do your releveling and you would get totally different results. Larry Brown a number of years, he got his Ph.D. thesis at Cornell, did a study of all of the tide gauges along the U.S. East Coast and all of the sea level stations there. Published it in Tectonic Physics. It was a rather obscure journal for such an important piece of work. And he noted that there was this discrepancy. He was unable at that time to resolve the difference and decide which was the true measure of sea level rise.

Both sea level tide gauge data and releveling for Portland and Eastport shows similar trends; that is, Eastport is clearly being submerged at a greater rate but as you correctly point out, the releveling data is several millimeters per year at a more rapid rate than is the tide gauge. I should say though that the releveling does not include the actual tide gauge. The station itself may be quite independently stationary or something with respect to the land in that area.

Dave Tyler is going to go out again this year and relevel the first order level network by a totally different technique than surveying than simple plain table surveying to see if he can come up with a new observation on the rate of subsidence of the land in that area.

DR. FINK: Is it something as simple, Joe, as the station, that you're reference station is also moving relative to Eastport? If it's going up while Eastport is going down, wouldn't that give you the increased rate of subsidence based on strictly sea leveling?

DR. KELLEY: Which station?

DR. FINK: Well, what are your reference stations?

DR. KELLEY: You mean reference stations? At Portland was the first order level.

DR. FINK: In other words, if Portland or Bangor as one of the stations you occupied, if that's going up relative to Eastport, that would introduce, that would double your rate or triple your rate, wouldn't it?

DR. KELLEY: Yes, but the leveling isn't tied to a particular station. That is one could tie a line from Bangor to Portland, Bangor to Eastport, and in each instance note that both of the coastal areas had subsided with relation to an inland area over the period of measurement.

I should point out that there are a number possible errors inherent in a surveying study. The rates are rather large. There is a possibility of error which is why he has decided to come in and not resurvey the line but using a satellite positioning and vertical location device to reoccupy the first order level network and ascertain whether or not there has been any real changes in the ground since then.

But I'll point out that coincident with all that seismicity in the area certainly is intriguing and one can speculate that hydroeustatic loading has had some effect both down east in Eastport and in the Portland area.

DR. FESSENDEN: Any further questions or comments?

MR. DONOVAN: Bill Donovan from the Army Corps. I'd just like to endorse the statement that this gentleman over here called to our attention just before this last set of comments on the better need to have a handle, the great difficult on translating into the economic values of the biological and other aspects of the marine and estuarial aquatic environments, not only along the Maine coast, the New England coast but indeed all the coasts we work on.

One of the real limitation we have from certainly the federal perspective is that those values and certainly they are real are classified as intangible values if you have to accept the definition that intangible is something, is a value that you cannot put a dollar figure on to make it a tangible value. Now,

we know that they are tangible in the ordinary sense. Nothing is more tangible than though values, but by economic definition these are very, very difficult values to get a hold of. And I believe they are real values and are significant and highly important.

But certain there is certainly a tremendous gap in all our research and so forth is that we're not able to translate those and get the appropriate handle on those and put them into tangible dollar values, and I would say -- and this seems to relate, of course, in part to some of the work we have to do in the regulatory aspects of the Corps permitting process, because the criteria are more stringent than ever, it would seem to me, to recognize an economic calculus in a tangible sense rather than the lesser perceived, the lesser valued intangible range of values that are in the biological and marine environment.

So this is a very great difficulty. I think we all recognize it is an area for needed continued research as difficult as it is to get greater emphasize in this area. So it is a significant thing and I'd like to say we appreciate this despite the difficulties we have responding to it.

MS. BRAATZ: I wanted to say that I have copies of two papers by Dave Aubrey and K. O. Emery on relative sea level changes, and I'll leave those upstairs in the room with the poster sessions.

DR. FESSENDEN: Any further comments, questions?

(No response.)

DR. FESSENDEN: Does anyone on the panel wish to make a last statement?

DR. KELLEY: One last statement. I should point out that Maine's tide gauges are, of course, on bedrock, which if it moves, it is largely a result of tectonic forces. I noted that each of the other speakers in this session showed a graph showing Atlantic City or Galveston or a number of other areas where the tide gauges are on barrier islands. All or most of the submergence of the Atlantic City certainly is due to groundwater withdrawal from beneath the barrier island, and is not simply the ocean level rising or any sort of the geological force. It's almost totally human induced.

DR. FESSENDEN: Okay, if there are no questions or comments.

(No response.)

DR. FESSENDEN: I would remind you then that the next session is going to be a concurrent double session. The Session A which is Planning Concept for Marinas and Maintenance Dredging will be held upstairs in the Ebb Tide Room, and that was across from the little area where we registered. Session B which is on Coastal Processes will be held here. So I suppose they will start in about five minutes or so. Thank you.

(A short recess was taken.)

MS. DICK: This session is going to be on Coastal Processes. Our first speaker is going to be Dr. Edward Thompson. He's Chief of the Coastal Oceanographic Branch at WES. He'll be talking about Nearshore Wave Transformation Along the New England Coast.

NEARSHORE WAVE TRANSFORMATION ALONG THE NEW ENGLAND COAST

DR. THOMPSON: Thank you, Jennifer.

My objectives for the next 20 minutes are two fold. First of all, I'd like to review some recent advances that we've made in modeling nearshore wave transformation. Secondly, I'd like to give you a very brief introduction to a radar device that we've recently acquired which we can use to get wave and current information along a coast. Both of these areas of advances have important applications along the New England coast as well as other coastal areas. Most of the wave transformation work I'll be talking about has been done under a research project we call Wave Estimation for Design.

I'd like to begin with a brief historical review of spectral wave models. I'll try not to get too technical in this review. About 25 years ago, Phillips proposed a saturation level for the energy that can occur at any particular frequency in the sea surface. That saturation level is commonly called the Phillips equilibrium level or the Phillips saturation level.

Pierson and Moskowitz soon thereafter looked at an extensive set of field data, and formulated an equation for the full spectrum of a fully developed sea surface. Most of the time in the ocean, the sea surface is not fully developed. The wind doesn't blow long enough to impart all of the energy to the sea surface that it could if it kept blowing longer; in other words, the storm ends before the sea is fully grown.

There was an experiment about fifteen years ago called the JONSWAP experiment, which resulted in the formulation of a spectral form for a <u>developing</u> sea. The JONSWAP spectral form is simply the Pierson/Moskowitz spectrum with another term, and the Pierson/Moskowitz term obviously embodies the Phillips equilibrium form. With each additional term we can describe a little bit more general situation. The JONSWAP spectrum collapses to a Pierson/Moskowitz spectrum when the sea becomes fully developed.

All of these formulations apply to deep water. The question of what happens when you get into shallow water has been a nagging question that wasn't resolved until fairly recently. There was some work done by Kitaigorodskii, Krasitskii, and Zaslavskii in 1975 -- It was published in the Journal of Physical Oceanography -- in which they hypothesized an equilibrium form for the spectrum in shallow water. There is a similarity form for the spectrum in deep water which can be expressed in terms of either frequency, which is the traditional choice, or wave number. They're interchangeable in deep water. When you go into shallow water they're not. If the formulation in terms of frequency is correct, the formulation in terms of wave number cannot carry over. And vice versa, if the wave number formulation is correct, the frequency formulation is not, and maybe neither one is correct.

Kitaigorodskii and his co-authors concluded that the formulation in terms of wave number is the proper way to carry the spectrum into shallow water. For purposes of computation, we still twist the expression into a frequency based expression. The ultimate shallow water spectral form is simply the JONSWAP

spectrum times a depth dependent factor, which, of course, is equal to one in deep water. The formulation and verification of the full spectrum was done by an international group in which CERC participated. The definitive reference is a paper by Bouws, Gunther, Rosenthal, and Vincent to be published in the Journal of Geophysical Research in 1985. The formulation is termed the TMA spectrum, where TMA stands for Texel, Marsen, and Arsloe, the three major field data sets involved in verifying the model.

According to the TMA spectral form, one expects the spectral energy to decrease very significantly as the water depth decreases, even at depths that are fairly large. Very dramatic decreases in spectral energy are predicted as one goes from deep water into shallow water even well before the customary point of wave breaking.

It's important to see how the theoretical formulation compares with data. Three sets of field data were used in checking the formulation originally, but we also did some fairly extensive comparisons with laboratory data to verify that this theoretical form is successful in explaining the modification of the spectrum in shallow water. The laboratory tests were done in a flume with a spectrum of wave energy coming over a 1 on 30 solid slope.

In some tests, we generated a JONSWAP spectrum at the paddle, and measured changes in the spectrum at various places over the slope. In shallow water, the very dramatic decreases in energy were apparent in both the measured spectra and the TMA predictions and they compared very well with each other.

We put the TMA spectral formulation to some more severe tests. Instead of generating a JONSWAP spectrum, we generated some very narrow swell type spectra. Obviously the TMA spectral form won't fit the deep water spectrum generated in the laboratory, but as you come into shallow water, the comparison actually became pretty good between the measurements and the theoretical formulation.

One last example, we generated a formless blob of energy and looked to see if that was tailored by the hydrodynamics of the situation to conform with the TMA limit. In fact it was; the actual shallow water spectrum compared very well with the theoretical prediction.

We implemented the TMA spectral form in one of our spectral numerical models. This was a state of the art numerical model. Once we added the TMA cutoff to the model, first of all, the initial wave height in 50 meter water depth was higher than the TMA limit said was possible, so we had to drop down significantly from that. Then rather than a decrease and then an increase due to shoaling, the TMA inclusive model predicted a continuous dropoff in the energy based significant wave height. This prediction compared pretty well with measurements from our Field Research Facility in North Carolina.

A second significant result in the area of wave transformation that has come out of our work recently is related to the formulation of the parameter significant wave height. If we define significant wave height, which is far and away the most often used wave height parameter in coastal engineering, as four times the standard deviation of the record, which again is the most common definition at present, we see in some laboratory data

as we go from fairly deep water to shallow water, a slight increase and then a dramatic decrease as the waves break and energy is strongly dissipated.

Traditionally the significant wave height has been defined as the average height of the one-third highest waves in the record. Until about ten years ago, that definition or an approximation to it was predominantly used. If you compute that parameter from the laboratory wave record, you get something that's very close to the energy based significant wave height in deep water, but differs very significantly at the point near wave breaking. There is a very dramatic increase in that parameter near breaking.

The difference between these two parameters should be disturbing to any who have not made any distinction between them in the past. Certainly it's of engineering significance getting up as high as 20, 25, 30 percent in some extreme cases.

Immediately we ask ourselves: Why is there this difference? All modern wave data collection programs are giving an energy based significant wave height. Digital data collection methods yield that parameter almost invariably. All modern computer hindcasting wave models are giving an energy based significant wave height estimate. How is it that it is not the same as the old H 1/3 that we've used in the past? The root of the problem is the fact that the shape of the wave changes dramatically in shallow water.

An example of a time series from Nags Head, North Carolina, shows waves which are near breaking in very shallow water near shore. The crests are narrow and peaked and the troughs are broad and shallow, a far cry from a sinusoidal wave. Similarly from laboratory tests with a broad spectrum, you can see the shapes of the waves are dramatically different in very shallow water versus deep water. The differences for a narrow spectrum are even more dramatic.

How then can we predict then the average height of the one-third highest waves from the energy based significant wave height or vice versa? We turn to Dean's stream function theory for an analytical framework for connecting those two parameters. We plotted the ratio of the average height of the one-third highest waves to the energy based wave height as a function of relative water depth, using the laboratory data. We also superimposed curves from Dean's stream function theory for different values of wave height over breaking wave height. Dean's theory was computed for monochromatic, uniform waves, so we can speak of a single wave height and a breaking wave height. The curve for H over HB equal to 0.75 forms a very nice envelope over the data. You can consider that as an upper limit to the values of H 1/3 over H MO.

We end up with a nomogram for predicting the ratio of average height of the one-third highest waves to energy based significant wave height as a function of nondimensional water depth. We formulated it so that there is an upper limit, the upper envelope on the data. A few field data sets also went into this comparison and they fit very well. There is also an "expected" curve which gives an unbiased estimate. After breaking, of course, the curve has to drop off, and the point at which that dropoff occurs is dependent on the wave steepness. We

have a family of curves for different steepness values for the the post-breaking condition.

Finally, I'd like to make a few comments on a radar device that we just recently purchased. The primary vehicle for doing this work at CERC is the Coastal Engineering Remote Sensing Applications Research Program. The device is called the Coastal Ocean Dynamics Applications Radar (CODAR). It's been discussed in various places in the literature for over ten years, although it's evolved a lot over that 10-year period. Since it has been a developmental system until very recently, I suspect many of you are not familiar with it and would be interested in a little information about the device that we have purchased.

Our CODAR is presently located on the south shore of Delaware Bay, going through a demonstration experiment in conjunction with a large NOAA experiment to measure currents in the bay. A second CODAR system has been leased for the experiment. The CODAR is capable of measuring both currents and directional wave spectra. The Delaware Bay test is strictly for currents. We plan a future test on the wave measuring capability next summer.

The antenna of the CODAR system is fairly small. Several people can carry it around without too much trouble. Another important point is that no part of the CODAR is in the water, so it's relatively insensitive to the sort of abuse that gauges in the water have to endure. The full system is quite portable. The electronics of a CODAR can easily be transported in a van.

The output from the CODAR software is conveniently displayed on a color monitor display screen and a small printer right at the site. The display includes current vectors over lower Delaware Bay at the time the data were collected, which represents about a 30-minute average. They represent surface currents over the top meter of water. Another nice result from the CODAR software is a measure of uncertainty of the predicted current at each point.

The CODAR is very appealing for several reasons. It's easily moved around. It's not so prone to damage. It gives information over a spatial area rather than just a point measurement. We feel that it's very promising for some applications in the Corps, and we look forward to it using it in various Division and District areas in the Corps in the future.

As the sun sets over the CODAR site, I conclude my presentation.

MS. DICK: Our next speaker will be Mr. Thomas Richardson. He's Chief of the Coastal Strategy and Evaluation Branch at WES. He'll be discussing Regional Coastal Processes Studies.

REGIONAL COASTAL PROCESSES STUDIES

MR. RICHARDSON: Before I start, I want to point out this is actually the Coastal Structures and Evaluation Branch, although I'm really not sure I don't like the way it's printed as the title in the program is better than the one I actually have. I guess if there is such a thing as a Freudian misprint, that might be it.

The idea in the Corps of Engineers of studying coastal processes on a regional scale -- by regional we mean scales of tens of miles or hundreds of miles, quantifying those processes over that region -- is quite new. The Corps in the past has tended to think in terms, for various reasons mostly because of authorization limits, tended to think in terms of specific projects that were usually at the most on the order of 5, 10 miles or so. And the coastal processes driving those products would be studied only to the scale necessary to understand and predict what would happen to that particular project.

There are two regional coastal studies underway in the Corps right now; one covering the entire coast of California, and the other which just began this year will cover the entire State of Florida, both Atlantic and Gulf coastlines.

The best way or one way I chose to try to get a handle on what Congress actually has in mind when they authorize a regional coastal study is to look at excerpts from the authorizing legislation for the two that are now underway. I won't read these verbatim. I think there are a couple of key things to pick out in the legislation. Both of these talk about comprehensive studies. The Corps is directed to undertake a comprehensive study. The Corps is directed to develop a comprehensive body of knowledge.

In both of these, the reference to shoreline erosion occurs -- you see shoreline erosion there and in the upper one. And this really gives the main thrust behind the genesis of these regional coastal studies. In both cases they were formulated to address coastal erosion problems that were large scale, wide spread and persistent on a regional basis, not just at a particular project site; and also erosion and potential for storm damages that could cause significant economic losses on a regional basis. So from a historic standpoint, both of those items had to be existing in the region before Congress would think about authorizing a regional coastal study.

The general mechanism that these studies have come to be under is a little bit different than the normal process the Corps undertakes to do a particular project study. Both of these have started with a tremendous amount of state and/or local interest. State and local entities or organizations, usually coastal related associations, have indicated to the Corps as a first step an interest in some kind of regional coastal processes study.

The second step has usually been that the state and local entities, representatives from the Corps, District, Division, Chief's office, the R&D community and the Corps, university, local universities and coastal associations -- such as in the case of Florida, the Florida Shore and Beach Preservation Association, or in the case of California, a local municipal organization in San Diego County called the San Diego Association of Governments -- would establish a planning committee, which would then hold meetings amongst themselves and also with other interested parties in the region to ascertain the feasibility of asking for such a study, number one, and number two, to ascertain what fiscal and political support might be in the region.

Once that step was successfully completed, then the planning committee would prepare a brief proposal, and this is a

copy -- I have copies of most of the documentation from these studies if anyone is interested in seeing it later on. This particular one is a copy of the proposal that was developed for the California study. There were people on the committee from the Scripps Institution of Oceanography, the California Department of Boating and Waterways. California Coastal Commission, which is a regulatory agency in the state, and several representatives from the Corps of Engineers.

Then the business of lobbying Congress for the authorization and appropriation for the regional study falls back on the state and coastal associations primarily. There is an lot of political support that has to be gathered to get something like this off the ground. In both instances, the local congressional delegations were invaluable in getting the studies authorized. And then if you're lucky, the final step, you'll receive the initial authorization and appropriation. It's not a continuing authorization, and the appropriation has to be renewed each year as the two stand now. But that is the final step to get you off the ground.

The California study was begun approximately three years ago. It was the prototype for what is rapidly developing into a program of regional coastal studies. The California study began efforts in a very limited area along the coast of California approximately 80 miles long. It was that area that the local coastal association, the San Diego Association of Governments, was interested in. So there was tremendous pressure to begin collecting data immediately in that section of coastline.

In retrospect, this probably isn't the best way to start out on a regional study of this nature. There is a tendency in starting something like this to immediately begin collecting data, and you can spend a lot of money and commit yourself to long-term efforts that may or may not give you much at the end of four or five years.

Based on the lessons learned from the California study and what's going on in the coast of Florida study right now, this is what appears to be developing as a synthesized general approach for regional coastal studies.

The first step is to divide the state into study regions, manageable areas of the state. And I use the term "state" here, it actually could be a collection of states such as New England. But somehow divide it up into manageable areas, usually on the scale of 100 to 200 miles in length, possibly a little longer. And then for each region to, number one, define the exact products the study will produce for that region. This is prior to any data collection taking place. This is interactive in that you're simultaneously identifying what the major coastal problems are in each region and inventorying what the existing information and data are for each region.

Only when these are completed for each region should you then look in terms of filling in the gaps in the existing data with collecting new data, and then the study can move into analyzing existing data, collecting new data, and finally starting to generate the products that were decided on at the outset of the study.

The key point here is the study itself is driven by the products and not the reverse.

This is a summary of the temporal, spatial and, most important, physical scales that the California study is operating under. I'll have a similar one later on for the Florida study.

The California study began in fiscal year 1982, and it has a proposed life of approximately ten years and as I said earlier, this has depended each year on new funding appropriations. There is no guarantee from year to year that Congress won't pull the rug out from under them. The estimated total funding over the 10-year life is somewhat less than $10 million directly appropriated by Congress to the study, and approximately $12 million worth of effort in the form of redirection or realignment of existing R&D works, mainly through the Coastal Engineering Research Center. These are R&D funds that are already programmed or already requested by CERC and in some form or fashion have been partially or totally modified or redirected towards supporting the goals in the coast of California study.

So you can actually see that the total dollar figure in terms of partial support is greater than what's expected to be directly appropriated by Congress. This is an important point to consider. It's virtually impossible to get enough funding in this day and age to support a large scale study totally on its own. You have to go to cooperative efforts of some sort.

The length of shoreline in California is approximately 1100 miles. It's 1100 miles roughly from the Oregon border to the Mexican border in the south, and the California study divided the state into six study regions. The primary data collection effort right now is centered in this 80 mile stretch of coastline from Danna Point in the north to the Mexican border at Tijuana on the south. This is an artificial boundary, a political boundary. The actual coastal processes boundary is several miles farther to the south.

I'd like very briefly to summarize the data collection that's underway in the coast of California study right now and again mainly in that 80 mile region of San Diego. The first one is directional wave gauging, and the study itself is supporting two nearshore directional wave gauges, plus one deep water directional buoy which is located outside or on the offshore side of San Clemente Island, which is one of the major islands sheltering Southern California from ocean waves.

In addition to the two supported directly by the study, three others are supported directly by the Coastal Field Data Collection Program, which is run through CERC. This is the first example of the type of additional support that's necessary for this kind of study. So you have a total of five nearshore wave gauges, plus one deep water directional buoy.

For beach and nearshore profiling, they have established 100 profile lines in the 80 mile stretch of the San Diego region, and ten of these have rod survey stakes driven in the bottom farther offshore than the normal survey extends. This is an attempt to measure long term shifts in sediment in the onshore-offshore direction. Divers periodically measure the sand elevations on the rods. Each profile line is surveyed twice a year and with one contingency survey per year in the event of large storm activity.

The next effort and one which has been completed for

the San Diego region is the development of historic shoreline change maps and analyses covering the time period from 1850 to present. These were done as a combined effort between CERC and the National Ocean Service. NOS produced change maps based on their "T" sheets. CERC is at present analyzing the shoreline change maps and quantifying the changes in their statistical characteristics.

The next item is a geomorphic framework study which was just recently released by Los Angeles District. It was done in-house by their geological folks. It's a very comprehensive analysis of geomorphic processes, geomorphic sediment characteristics, and the general geology of the San Diego region.

The next item being supported by the study at present in the San Diego region is river discharge measurements. This is both sediment discharge and water discharge. Basically what they're doing here is supporting six USGS gauging stations on six rivers in Southern California, all of which have periodic water and sediment discharges.

Aerial photography, the whole coastline in Southern California is being flown twice per year on a scheduled basis, on a pre- and post-winter schedule, and then twice per year on an unscheduled basis in the event of large storm activity.

And then finally sediment sampling. Approximately 40 of the beach and nearshore profile lines have been sampled or are being sampled during the first year of data collection. This will be continued at a somewhat reduced temporal and spatial frequency as the study proceeds.

I mentioned the R&D support to the coast of California study. This is a summary of the nature that support has taken so far. It's particularly taken the form of two things -- redirection of existing research work units and supplementary data collection through our Coastal Field Data Collection Program and the Monitoring Completed Coastal Projects Program.

I won't go into a lot of detail on this. One of the major efforts under the research work units is the development of a regional coastal processes numerical modeling system. The dollar value just over the four years of FY84 through FY87 when this research work ends is approximately 3.7 million, and of the data collection which supports a wave data collection and analysis facility at Scripps Institution, the wave information study, a 20-year hindcast in deep water, and nearshore transformation hindcast on the West Coast, the development of a coastal data base management system, and then finally the Monitoring Completed Coastal Projects Program which is monitoring a project at Imperial Beach in Southern California right now. Total dollar value of that over four years is 3.8 million for a total of approximately $7.6 million in either direct or indirect support over a 4-year period to the coast of California study.

The coast of Florida study is in its infancy. It began this fiscal year. It has a proposed life of one year, FY85, for reconnaissance, in which Congress has directed the Jacksonville District of the Corps to produce a plan of study for the entire coast of Florida, and with an estimated 8 years following that to actually perform the study. Estimated total funding will be about $5.5 million direct federal funding to the Corps, an estimated $8.4 million worth of work in kind by the

state. This consists primarily of existing data collection that the State of Florida supports internally. They have a series of profiles around the state. They'll continue to collect data on those beach and nearshore profiles, aerial photographs, and possibly intensify some of their efforts to support this study. The dollar value of the R&D support and the nature of it is as yet undetermined. That's something that will be worked out in this first year of reconnaissance.

Total shoreline length of Florida is roughly the same as California, about 1266 miles. They're looking at dividing the state into anywhere from 3 to 11 or possibly more regions, probably somewhere in between those two figures because I can't see it going much beyond 11. The general status of any data collection -- well, there is no data collection right now, but the study approach formulation is currently underway. So that's something that is developing even as we speak.

The next two viewgraphs summarize suggestions we have made and we've discussed with the people responsible for performing the study for possible products from the coast of Florida study. I think they represent the general class of products that one should consider in any kind of regional setting anywhere in the United States for a regional coastal processes study.

For each region, the first class of product would be a model or system of models of coastal processes, and I use "models" here in the loosest sense possible. People tend to think in terms of models as either being numerical or physical. But numerical, analytical, geomorphic, you name it, just some way of tying together what we found out about the region into a methodology that can be then used for prediction on a regional scale. The thrust of that is the prediction ability of the model. These are some of the types of models that were suggested for consideration in Florida.

The second class of products that should be considered for each region is a documented history of coastal processes effects and causes in that region. Shoreline change maps, beach profiles, storm effects, and most importantly, man-made effects, especially in Florida which has a very heavily engineered coastline. This provides the historic framework that you need to look at in order to put the predictive results from your model in the proper perspective.

And then for each region we suggested producing what we call a coastal planning manual which would give -- this is designed to be a product usable by people within the Corps, state agencies, inside and outside of the Corps of Engineers, local consulting firms, any one that is interested in regional effects of changes in the coastal processes.

This will give an overview of coastal processes in a region and would also describe methods or uses for employing the study products, what the study will produce. It would sort of be a summary of what the study did in that region.

Then for the entire state I think it's very important not to lose the information and knowledge that was gained during the 8 to 10 year period of the study. There's a tendency that we're all subject to to collect data and put it in a shoe box someplace, put it in a filing cabinet and then when you

move on to another job or somebody else moves into your slot, nobody knows where the data is, nobody knows what it was used for, what's its characteristics were, when it was collected. So it's very important when you're doing a large scale study like this to set up some sort of computer based information and data management system that would catalog the existence and location of all data both existing and new data uncovered or collected by the study and would also contain selected data summaries and selected records of data. This is a way of insuring that the benefits of the study live on past its lifetime.

This final viewgraph summarizes what what are beginning to emerge as the most important considerations in both planning and conducting regional coastal studies. Number one, starting out with the correct approach. Don't jump into data collection immediately but stand back and take a long look at what you're after. The study has to be driven by products from the outset. Support work from the R&D community, work in kind from the R&D community or state and state and local agencies is extremely important for funding reasons and also for continued political support.

Some type of data management system is essential, as I just discussed. State and local support is absolutely essential because the study has to be resupported, rejustified each year. New data collection, new research and development should be done only when no other source of information is available. You should in each case justify taking new data and doing new R&D as part of the study.

And then finally, because two are underway, I know several other areas in the United States are interested in developing regional coastal studies, there's beginning to emerge a national perspective on these that may become increasingly important. The Corps may begin seeing guidelines from OCE on what these studies entail, how they should be conducted, and what their limitations should be. Thank you very much.

MS. DICK: Our next speaker will be Lee Butler. He's Chief of the Coastal Processes Branch at WES, and he'll be discussing the Frequency of Wave Overtopping Volumes at Roughans Point.

FREQUENCY OF WAVE OVERTOPPING VOLUMES AT ROUGHANS POINT

MR. BUTLER: Thank you, Jennifer.

The project I'm going to be talking about is currently underway at the Waterways Experiment Station, and all slides are depicting what we are going to be doing. We do not have results as yet. Presently, we are a third of the way into the study. So curves are really drawn from a hypothetical point of view.

The problem I'm presenting is a flood level prediction study at Roughans Point, and I think a picture is worth a thousand words. Here is a picture of devastation left by the February 1978 blizzard that struck the area, and here is a view of the Roughans Point area.

The inundation did not come from any surge. It came from the waves on top of the surge that overtopped the present

protection area. The area we are looking at is a coastal reach just north of Boston called Roughans Point.

The study also involves areas north of the Roughans Point along Revere Beach as well as interest in flood levels behind the Point of Pines in the Saugus and Pines Rivers Basin. But what I will concentrate on is the Roughans Point study.

Roughans Point itself, at least the area susceptible to inundation covers about 55 acres behind the protective structures, and you can see the present outline of the area in red. There is a drainage capability but the problem is that when you receive a tremendous quantity of water coming over the existing structures, the drainage system simply cannot handle it. There are historically high ponding levels, for example in the '78 event, levels were on the order of 8 feet in some areas.

Here is a section of the existing north wall to the area, and the heights of the wall were anywhere from 10 to 17 feet. An east wall section shown here has an existing structure with a curved parapet as well as straight line sections with a block wall and different types of revetment in front of the structures.

Here is the problem. With the shoreline having retreated to its present condition, even under very high tide events, you can get substantial overtopping. What we have tried to do at the Waterways Experiment Station is to propose a way to approach obtaining the frequency of wave overtopping levels in the Roughans Point area.

Here is a slide that depicts the existing condition for the east wall. There is a concrete structure and some existing revetment. The District has proposed to place some sort of a berm, stone structure, in front of the existing wall to reduce the wave energy and hence reduce the wave overtopping.

So what are we trying to get out of the study? What we are really after as a final product is a wave overtopping rate versus return period.

The approach involves the conjunctive use of four separate models to obtain the final product. We will be employing a hydrodynamic model, wave model, probability model, and a physical model. The goal is to try to formulate a final overtopping rate frequency by integrating the results from these four modeling efforts.

Physical model efforts include running flume tests with eastern and north wall sections. Tests include running various combinations of water levels and significant wave heights and periods. The result of this effort will be nomographs of overtopping rate. Predefined waves are run in the flume toward the structure and amount of overtopping that occurs for each combination of significant periods, heights, and various water levels is quantified. Hopefully, from these tests we will be able to get a relationship between wave height and overtopping rate for various periods and water levels.

The approach is to then take these sets of curves and interpolate a rate of wave overtopping for actual storm events. Numerical models are used to model storm hydrodynamics and associated wave climatology.

As far as the wave modelings itself, we are applying the spectral wave model presented by Dr. Thompson. Using

information developed in a study performed at the Waterways Experiment Station, called the Wave Information Study, we are bringing in the deep water spectrum into the area, handling the diffraction, and translating it to the project at Roughans Point.

As far as the surge and probability modeling, I will discuss these two subjects together because of the problem of selecting which event one wants to model.

First we consider the events themselves and how we will assign some kind of probability associated with a given surge and wave event. We used the long history of data at the Boston gauge and extracted from this the various historical records, the storm surge for events over the last 80 to a hundred years. From this set of Boston gauge data we can derive a partial duration series.

This slide shows you what one event looks like. It is the January 13, 1964 storm at Boston. The wind is taken from Logan Airport, and the astronomical tide (in yellow) is from predicted tide levels.

Once we have the partial duration series that gives us a frequency of surge levels at Boston, how do we consider all possible combinations with the tidal event? This is accomplished by a convolution of surge profiles with representative tide events. This slide depicts an example, and you can see that, depending upon how the surge envelope coincides with the particular phase lag of the tide, you can get different results for the total water level.

We intend to take a mean seasonal tidal period or record, say six months, and using a one hour lag, convolve approximately 30 representative historical surge profiles with the tidal record to derive about 130,000 possible surge plus tide affecting the project area.

The question now is how to pick which events to model? You certainly do not want to run all 130,000 events. So then the problem is to derive some procedure to select the events to model. The approach is to form a distribution of all the events by wave height or by water level, which is shown here, and then to try to segment the curve. You can see on the slide, the curve on the right shows the typical exceedence probability and how this distribution of events relates to the exceedence curve if you treat the probabilities in a cumulative sense.

This slide shows an enlargement of a small portion of the curve. The actual selection of events is accomplished by segmenting the curve by water level. Within each segment we randomly select events, surge plus tide events within each segment, and use the exceedence curve to assign lumps of probability mass to the event. What we expect from past experience is to end up modeling about 100 to 150 events to obtain acceptable confidence levels in the results.

Once we have the events selected, we can then move on to the hydrodynamic model. By drawing a correlation with the Boston gauge, open sea boundary conditions can be established for the various storm/tide events. This slide depicts a typical grid. This is not the actual grid that will be used but only demonstrates the typical grid to be used in the hydrodynamic model. The hydrodynamic model is the WIFM model that Dr. Houston mentioned in his talk this morning.

After all of these model applications, we still need to develop the final overtopping rate versus return period. This is accomplished by using the still water elevations from the hydrodynamic models and wave parameters in running concurrent wave models with the storm event. Using the overtopping nomographs from the physical model, we are able to make a probability assignment. The wave overtopping is tied to the meteorological event, allowing assignment of lumps of probability. For the event itself, we can also assign probability, and by accumulating these probabilities for all 100 to 150 events, we can arrive at our overtopping rate frequency.

So in summary, we have made conjunctive use of a number of models to address the complex problem of obtaining overtopping rate frequencies at Roughans Point. I do not believe this type of application has been tried before. Again, we are right in the middle of the study, but are looking for results for the project in the late winter or very early spring. Thank you.

MS. DICK: Does anybody have any questions to ask any of the speakers?

MR. DONOVAN: Bill Donovan with the Army Corps.

I'll just make a comment on the coast of California storm and tidal wave study. It should be clear that is not an R&D study, although it has serious R&D implications. It's a planning study that was funded by the Congress. It did not explicitly state anything about the R&D elements, although obviously there are significant implications as was brought out here in supporting that study. But that is why the study itself is being done by the South Pacific Division of the Corps under the Los Angeles District.

I'd say the numbers I see presented on the slide for the $10 million or less, it seems to me highly unlikely based on the progress of that study to date, a rather slow start actually, that the entire coast of California study will be done for less than the $10 million that's outlined as suggested there.

And also, the legislation that the Congress enacted that directed the start of that study has implications for the entire West Coast; that is, from Tijuana to the line up at British Columbia actually. So the California aspect of it is at least intendedly the start of it could be an entire West Coast study over an extended period of time. I don't recall the time element on that.

But that study I think in it's inception points up, because it's a new type of study, a planning oriented study not leading to any authorizations of any kind, not what we'd call a bread and butter study, that it does point up the great difficulties of organizing at the outset, because we don't have a lot of experience in organizing or getting squared away for that type of a study, and I think as that has gotten started, that has reflected that. There has been a lot of adjustments. I'm involved in the oversight group for OCE that reviews that study, so I have some familiarity with it.

It does have significant R&D implications and needs certainly, but the R&D work that's being done there I think is paralleling some of the study, and I don't know about the transfer of funds in there, but it is not specifically an R&D study. It is a planning study. Thank you.

MS. DICK: Thank you. You had a question back there?

MR. BAER: Actually I have two questions if I could ask them. The first to Ed Thompson. The TMA is very interest, as you presented. It's the first time I've seen it. Does that imply that the shape of the offshore bottom topography is not important, just the depth? That's what it looked like in your slides.

DR. THOMPSON: No, that's just an upper bound on the spectrum. Obviously if you are below that bound, the topography is very important. But if the topography modifies the waves as they come into shallow water such that they would tend to go over that bound, in other words, if refraction is focusing energy, then I suspected it would be limited by that.

MR. BAER: Just simple steepness would -- as long as it's not above a certain level, it doesn't matter then, above a certain rate of steepness?

DR. THOMPSON: Yes, I think that's a saturation curve for the function of frequency.

MR. BAER: Are there reprints of that work available somewhere?

DR. THOMPSON: Yes. The study in various levels of detail are trickling out, but there are some things in print already. One thing that comes to mind is the paper Glenwood Vincent and I presented at Coastal Structures 83. If you'd like, I could scare up a copy for you.

MR. BAER: I'd appreciate it. Thank you.

Then could I ask Lee Butler a question here. I didn't completely understand the separation of the waves and the surge in the two models. If I'm understanding the presentation right, the waves come out of the long-term hindcast that WES did and the surge comes out independently, and you're mixing those in a probability sense. Am I understand it right?

MR. BUTLER: Not quite. I probably didn't take enough time to explain that. But what we're doing is with the 100 to 150 events that we're running, we were also running the spectral wave model concurrently with it to essentially hindcast the waves that would have occurred during that surge tide event. Knowing the waves for that event given the water level of the surge tide, we then interpolate from the nomographs for overtopping. Sorry I didn't explain it the first time.

MS. DICK: Are there any other questions?

(No response.)

MS. DICK: Does anyone on the panel want to say anything?

(No response.)

MS. DICK: Okay, that ends the discussion.

MR. BRUHA: I have a couple of announcements again. Number one, I have a couple of handouts at my table if you'd like to each take one. They pertain one to tonight's session which begins at 7:30, and the other is a questionnaire which you'll all be getting tomorrow, but if you want to take one in advance, you can go ahead and take one. So if you would, please, consider tonight's session. When you see who is on the agenda and what's going to happen, I think you'll find it will be very interesting, and I know it's Halloween, but you know, make the sacrifice. Thank you.

SESSION A
PLANNING CONCEPT FOR MARINAS AND MAINTENANCE DREDGING

MR. SMITH: This session will be on Planning Concepts for Marinas and Maintenance Dredging. The first speaker is Neil W. Ross, Sea Grant Marina Advisory Service, University of Rhode Island, and he will talk on the subject of Concepts for More Efficient Marina Use of Water Area.

CONCEPTS FOR MORE EFFICIENT MARINA USE OF WATER AREA

THE NEED TO EXPAND MARINA CAPACITY

MR. ROSS: Marinas, boatyards, yacht clubs, and launching ramps provide the only way most Americans have to get their boats onto the water, and thus those facilities qualify as major points for the public to access recreational waterways. They are like the narrow neck of the hourglass of recreational boating, with the sand made of boats, engines, accessories, and the boating public. On the dry land side of that hourglass's neck are the people who want to buy boats which support manufacturers, wholesalers, and dealers. On the other side are the many recreational waters of our great land. People and products can only go out and return through that narrow neck -- the boating facility.

Boatyards, yacht clubs, and marinas are major public access points (all are referred to as "marina" in this paper). Whether they are public marinas or privately owned/managed, each provides similar access to boating. One government planner has found that for every new slip added in his region, one new boat is sold. Conversely, for every slip lost to conversion of marinas into other non-boating uses, there is a reduction in boating access. One southern boat manufacturer (making a full range of boat sizes sold in every rigion of the US) recently told me that he could sll all the big boats (35 foot plus) and small trailerable boats he can make, but the middle size boats (20-35 footers) are not moving. Lack of slip space, he believes is responsible. Certainly this is not true everywhere, but a growing trend points to the need to expand existing facilities and open new marinas. What will happen in the states (i.e. Florida and Connecticut) which are losing marinas and boatyards faster than they are being built?

The space squeeze on marinas and boatyards has also translated into higher costs for the small percent of lucky boat owners getting dockage. Will tomorrow's young American middle class families be able to find slips, as did their parents who turned the restricted "yachting" into the broadly available "boating" in the 1950s through 1970s? The only way they will today is if the nation's boating access expands.

TRENDS IN BOAT POPULATION AND BOATING FACIITIES

Year	No. Boats (millions)	Boating Facilities (marinas, boatyards, yacht clubs)
1960	8,025	5,150

1965	7,865	5,400
1970	8,814	5,900
1975	9,740	5,995
1980	11,832	5,850
1984	13,489	5,789

(Compiled by Neil Ross, URI from MAREX annual reports)

Thus while our nation's recreation fleet increased by 68 percent during the 24 years from 1960 to 1984, the number of facilities only expanded by 12.4 percent. No figures are available on the relative changes in the total number of slips. National figures do suggest that the number of facilities have been steadily decreasing (down 236) from a high of 6,025 in 1976. This trend is of great concern to the marina industry, boat/engine manufacturers, coastal planners, and the boating public. (Source: MAREX-NMMA in Boating Industry Magazine, January , 1985.)

ALTERNATIVE MARINA CONCEPTS

The two-boat per slip dockage, 90 degrees to the walkway (with a finger float on one side of each boat), is the most common berthing plan. It is used in over 95 percent of marinas in the United States today. The second most common arrangement is the single boat per slip, with 90 degree finger floats (one on each side of the boat) and is estimated to be in under 25 percent of the facilities. Most marinas utilize a few piers or t-dock heads for parallel docking (boats tied broadside to the pier).

Less common (estimated under 8 percent) in marinas are the angle docks at 60 degrees, with either double or single boat berthing. Very common in Europe but rarely seen in America are the perpendicular docking system (90 degrees parking) without any finger floats between boats at all. The latter requires special mooring or anchoring schemes.

Each system has advantages and disadvantages in cost of construction, ease of use, convenience, and familiarity. They each also accommodate relatively different numbers of boats per acre of water surface by modifying the area occupied by either finger floats/piers or fairway for boat turning.

ILLUSTRATION TO COMPARE ALTERNATIVE DOCKING DESIGNS

To illustrate the relative space efficiencies of these alternative docking designs, lets look at simple marinas with boats 30 feet long by 10 feet wide. Docks are designed with main walkways 6 feet wide and fingers 4 feet wide (when used). Two feet per boat beam is added for fenders and ease of movement in and out of the slip. The fairway (channelway between the ends of facing slips) is 1.5 times the boat length slips at 90 degrees, 1.0 times the boat length for 60 degree slips, and 2.0 times the boat beam for parallel berthing.

SUMMARY TABLE: COMPARING SLIP ALTERNATIVES

Berth Option	Finger Width	Fairway	Boat's Total Area	No. Boats per Acre	Ratio	Slip Efficiency Ranking

90 deg. fingers 2 boats/slip	4'	45'	777ft2	56	1.00	4
90 deg. fingers 1 boat/slip	4'	45'	888ft2	49	0.88	6
60 deg. fingers 2 boats/slip	4'	30'	711ft2	61	1.09	2
60 deg. fingers 1 boat/slip	4'	30'	813ft2	54	0.96	5
Parallel docking no fingers	0'	20'	759ft2	57	1.02	3
Perpendicular docking, no fingers	0'	45'	666ft2	65	1.17	1

From this example, with the 90 degree fingers with 2 boats per slip as the common standard, it is clear to see that Europe's perpendicular no-finger system is the most efficient with 9 more boats per acre (16 more than the least efficient single boat slip at 90 degrees). The 60 degrees double slip is second largely due to the reduced area used in the fairway. In third place is the parallel docking with the narrowest fairway but fewest boats per length of walkway.

While real marinas are a mixture of boat and slip sizes, the principle remains the same -- it is possible to increase slip capacity in existing docking areas. There are some sacrifices of convenience. However, in addition to more boats by eliminating by eliminating fingers, there are significant savings in capital construction costs, maintenance, and property taxes. Increased marina space efficiency could translate into improved business profits, reduced growth of slip rental rates, and, most important, more boating access for new boaters.

MR. SMITH: The subject of the next talk is Marina Case Studies. Mr. Steven Onysko, Professional Engineer, Consulting Engineer in Rhode Island. The floor is yours, Steve.

MARINA CASE STUDIES

MR. ONYSKO: Thank you, John.

There are so many familiar faces around here I feel like I'm back working for the Corps of Engineers. I don't have a prepared speech, so I'll just talk from these slides.

Is there anyone here that doesn't know where Newport Harbor is? The former site of the Americas Cup Races.

Okay, Newport Harbor is located in southern New England on the mouth of Narragansett Bay. It has been a very important seaport since the days of the revolution and also when the British occupied the city of Newport. The harbor is actually on Aquidneck Island. The harbor is right here on this slide. It's been famous for such things as the rum-molasses-slave trade, and also the whaling industry. It was the site of the naval base in World War I and Warld War II right up until about 1972, when

the navy pulled out.

This is a slide of the boast chart of the harbor. This is Goat Island, where torpedos were made for the navy. Somebody at lunch asked about Rose Island. Here's Rose Island just below the Newport Bridge. There's Fort Adams, Brenton Cove, Ida Lewis Yacht Club, and this is the Thames Street waterfront, where all the commercial development is located.

This slide shows the Corps of Engineers project in Newport Harbor. It was started in 1907 and completed in 1940 at a cost of about $498,000. There are actually two channels. There's a channel within a channel. Here's the 21 foot channel around Goat Island within an 18 foot channel. there's an 18 foot anchorage here and a 13 foot anchorage there. These are some slides of the Narragansett Bay area. This is Rose Island again. This is Brenton Cove. These are all single point moorings that are operated by the city of Newport and the Harbormaster. This is looking a little bit further to the east, Goat Island again as I pointed out. This is the Naval War College facility. This is the Melville area up in here and this is the harbor itself. Here's the 18 foot anchorage I pointed out and this is the 13 foot anchorage. This is the inner harbor along Thames Street. These are all fixed piers, all timber docks and piers. Originally there were very few floats in Newport Harbor. The Newport Yacht Club had a few floats however.

There have been a lot of changes since the navy left in 1972 and they have changed the character of the harbor itself, and of course the local people are quite upset about it. This slide shows one of my projects. It's called Coddington Landing which I will tell you a little more about. I'll also tell you about a few more projects which I was involved with. The Coddington Landing facility has a 145 foot water frontage and about one acre of land. The land cost $950,000. That's almost a million dollars an acre. It was a former home heating oil distribution site. The first land developer asked me to design a marina that would have 30 slips for 30 condominiums. There were a lot of problems here because of the riparian extension lines, and the harbor line here, and it took quite a lot of planning to arrive at something that would accommodate 30 boats within the narrow shore front.

The first developer ran out of money and he sold the property. The second developer then went bankrupt. The third developer bought it from the bank. He was one of my previous clients, and that's why I finally got this particular job. The reason this marina was able to go in this particular area was because I provided what I call an "abutters channel" here, and also an "access channel" to get to this little canal, which belongs to the city of Newport. There was an awful lot of red tape in this project. The city of Newport required us to apply for a permit to dispose of dredged material within the city limits, and I looked at 18 different sites, but there were only two that were suitable.

The contractor that got the dredging job was very inexperienced. In fact this was the first dredging job he had ever done. With a little supervision and instruction, he put up this dike shown here, which he dug right out of the adjacent land with a bulldozer. Now I tried to tell him that he needed a little

more width at the top, but this slide shows how fragize it turned out. This disposal area was supposed to be filled a couple of times. After the first filling, it was supposed to be dried out, then taken to the dump site and then filled again. But time was of the essence and the contractor used this ten inch dredge shown in this slide, to continually fill the disposal site, and was very inefficient.

He took the job for $50,000, started on March 10 and on 23 March he had to stop because he ran into some shale and large boulders and the machine couldn't handle it. The dikes were becoming saturated, so he put up this plastic on the dike thnking that it would prevent the water from seeping through, and of course it didn't. These composite photos show the kind of material that was pumped out. Progress was very slow and they finally realized that they had to get another dredge. This slide shows the dredge they rented from Hydro-Dredge, which is a 24 inch cutter with a 16 inch discharge. They kept pumping round the clock and this slide shows the kind of material they encountered. Progress started kind of slowly and then it pumped pretty well. Here are some of the boulders that came out of the pipe. Apparently during the sailboat era cargo boats used those large boulders for ballast. They may have used them during the slave trade but I'm not sure.

When they wanted to put cargo on in in Newport it appears that they just threw the ballast overboard in this particular section of the cove. As you can see the material dried out very quickly. This slide shows the young boy running along there, and here it is just before it's starting to get filled up to the top. They pumped 24 hours a day. These slides show the plant that they used. The cutter head is down here. The pipes come back here on the floats. Here are a few more pictures with the cutter head up and the floats there, and that's the tug that was tending the dredge.

Like I said, the disposal area was supposed to be filled twice, but time was of the essence and they started to build up more storage area by bulldozing the material up higher and higher. You can see how the bulldozer got right inside the diked area and the conditions under which it was working. The stream of water shown in this slide was so forceful, I told the bulldozer operator that if he didn't wear a life vest I'd report him to the Coast Guard. You can see how high the dredged material is starting to come up here.

This slide shows a breach through the dike. They had a single effluent pipe through here, but the contractor still kept on pumping anyway. He repaired the breach later and put in four different pipes through there. He also put the effluent settlement basin and some hay bales around there. The hay bales finally washed away and you can see that the sediment went into the harbor.

This slide shows the dredge operating in pea soup fog. The dredging, the spoil storage and disposal was a major logistical problem here. You can see in this slide how the dike was leaking like crazy, and the amount of sediment that went out into the harbor. You can also see the extent of the material over here. The dredge was there for 18 days at a cost of $10,000 a day, so it cost $180,000 to dredge the materials.

You can see how the dredged material was built up above the plastic cover on the dike. Here's some pictures showing it was drying out. As you can see, the height of the material was over 30 feet. That particular area shown here on the back slide was wet, so they bulldozed it up into a pile to let it dry out a little bit quicker. This slide shows some of the sediment that broke through the dike on the back side and it spread out over in the back. Here's how they took it away to the disposal site. They used a pay loader and a truck. The cost was three dollars a yard to take out about 30,000 cubic yards. They deposited it in an area about 5 miles to the northeast. I understand the hauling contractor subsequently sold the 30,000 yards for six dollars a yard for fill. The pseudo environmentalists and arm chair ecologists were saying it was odifferous and polluted and everything else but it was the best fill that the contractor had ever sold.

This slide shows the deposition site after the dredged material was removed. As you can see, it was dressed up nice and clean just like it was in the beginning. The overall disposal was also a major logistical problem.

This slide shows the driving of the wooden piles for the marina. They couldn't get the required penetration so they used steel piles. The steel piles didn't penetrate much further because they hit ledge. We later found out that the boring information was wrong and they had to drill holes in the rock for the piles. The contractor wanted to switch back to the cheaper wooden piles again, but I said nothing doing because if he ever put the wooden piles in and they broke off, they'd never find the hole again to replace the pile. They drilled the holes with a regular artesian well rig. They put the rig and this little crane on the barge, shown in this slide. The piles were filled with concrete and reinforcing rods.

Here's a couple of pictures that show how they put the marina floats in. They drove the outer southerly piles, connected all the floats and then drove the piles at the ends of the finger floats, so they're right in line. If you ever try to do it the other way, you'll never get them in line.

Here's the barge again, looking from the top of the condominium building. This slide shows that some of the floats are already in place and the facility is not quite completed. This slide shows the completed marina was filled with boats in the summer of '83. They had over 60 boats in here. The 30 slips were so wide were able to fit another boat in the slips, as well as along th e southerly side. The floats cost $119,000 and they made $94,000 just from the rental during the Americas Cup season.

You can see the dredging turbidity ploom in this aerial slide. They finished the dredging June 1 and this photo was taken on July 11th. I estimate that that ploom was here for 2-3 months. What had happened was that they cut away all of the vegetation in the marina area, this dark spot is vegetation, and the exposed soft material and sediment just went back and forth with the tide. The boat propellers also kept stirring it up from on the bottom. The area is nice and clean there now.

Some of the developers and contractors listen to you, but others don't and they design and build their own floats like the ones shown here. The electric cables under the

articulated connections was their design. It cost them $5,000 just to snake the cable back through the floats in the fall. This slide shows the badly damaged ends of the floats. Some of the connections just broke right away.

Okay, now this lide shows the finished marina. As you can see there's quite a bit of space between finger floats, but it was designed that way because we tried to take advantage of the whole area. Every site is different, every marina is different in the size of the boats and everything else. We took advantage of the space here so we could get a 110 foot boat and a 40 foot to 110 foot to 150 foot boat here.

The condominium facility itself cost $5,000,000. The marina, the dredging and everything else was $650,000. I used to use $4,000 per slip to estimate the cost of a marina. This particular marina was $650,000 divided by 30 slips, for a final cost of $21,666 per slip.

All right now, this slide shows another project I worked on. This is the old Newport shipyard which is now the Newport Offshore Shipyard. Right after the completion of the Americas Cup Races, the shipyard realized they were going to be out of business pretty soon because the city raised their taxes a considerable amount. They sold this property to the same developer of Coddington Landing for $2,500,000. The land area was about 2 1/2 acres, therefore, property along the Newport waterfront is about $1,000,000 an acre.

Again, all hard docks out here, a travel lift over there. I took out all the hard docks and travel lift pier and designed for 65 slips, so we could use the adjacent waterway as a fairway, and so the boats at Ann Street could use it also. As you can see on this permit application plan, all this "xing" is where we took everything out of here. Everything was going along fine and the owners built this model of the marina and hotel timeshare complex. Of course my input was just the marina, design of the marina and getting the permits as well as supervising the construction.

This slide shows Ann Street pier, which is owned by the city. They cmae out with plans to put in 30 floating slips extending 360 feet out to the harbor line. It would have interfered with our plan and other abutting property owners riparian rights. Our original plan to use a common fairway had to be dropped. So what I did was to redesign this section here and use the existing pier. That way we maintained all of the property owners.

Designing marinas is a continual process, one is continually planning, designing, making changes, etc. it seems you're never through until construction is completed. These slides show that the old dock was pretty delapitated. I had to redesign it, take off all the deck, all of the stringers and all of the headers. We left the piles in, just so that we'd have the orignal alignment. This is the old Ranger Shed used in 1936 as the oerations center for the Americas Cup.

This slide shows they are starting to put on the new planking for the dock and here are some of the new floats. The developer listened to me this time and he made a raceway here, as I suggested, for the electrical wires. This slide shows how they're putting piles in. The flotation blocks on the floats were

fastened with nylon straps. Even before they got them in the water, some of the straps had broken. This facility is being operated as a commercial marina and at this time it does not go along with the 65 unit hotel. This slide was taken in August and shows the marina is not quite completed. The boats shown here are going to be in there this winter, and the owners are going to live on them.

The developer made $80,000 on slip rentals already this summer. The overall cost of the marina is projected to be $969,000. That comes out to be about $14,950 per slip. That's quite a bit of money for a slip, but in Newport they can get it.

Now this slide shows the Newport Yachting Center in Newport Harbor, which is another one of my marina projects. The probjem here was inefficient, deteriorated fixed docks. The facility was also going to be used for "in the water" boat shows, as well as a marina, so I designed removable floats on the ends, so that people could walk completely around the facility without back-tracking. The owner thought they needed a floating breakwater to protect their facility, so he bought a 30 foot wide and 80 foot long barge. I said it would not work as a floating breakwater. He bought it anyway and found out it didn't work, so now he put it over here and he uses it as a cocktail lounge area.

It wasn't all work. I was at the right place at the right time. This is the Newport Offshore Shipyard site. The owner of Newport Offshore, which I had as a client, asked if I could design and build a single point lift for the Defender Courageous Americas Cup Challenger Syndicate here. This slide shows us starting the lift and here it is when it was completed. From the time we started the design, got the plans done, got the permits and constructed it, it took 12 days. Now you ask, how could you do this? Well, we got a letter of permission from the Coastal Resource and Management Council and also a letter of permission from the Corps of Engineers, because it was only going to be up there for two years. It's been up there 1 1/2 years and they are going to take it down pretty soon.

I was invited to the launching of the Defender Yacht which is in the lift here, and the Courageous is over there in this slide. I was able to go out and participate in some of their trials. This slide shows the Defender and here's the Checkered Demon which is the tender for the Defender. This shot shows the Eagle, which is the tender for Courageous. Here we are towing the Courageous out to the race course in Rhode Island Sound. This is the Checkered Demon with a big enflatable orange buoy marker. After the two boats raced across the starting line, we would race like crazy seven miles down the line and throw the orange marker overboard and wait for the boats to go around it, then pick it up and drop it some place else along the race course.

One day they were short a crew member and I spend about four hours helping them drive the boat. This slide shows howmuch I was enjoying it. The sailboat crews race 4, 5, 6 hours on the water, and when it comes time for lunch, they drop the main sail and sit down and have a liesurely cruise and eat their lunch.

This slide shows the Defender and Courageous racing, and here they are coming to the line.

The Newport Offshore Shipyard had five American Cup Contenders berthed at their facility at one time. This is the

Australia II. This is the Austraila Challenger. This is the Italian Contender, the Azura, and this is the French Contender, France III. Excuse me, there were six. There was also the Defender and the Courageous that were on the other side. This slide shows the Australia II, with their secret keel covered up.

This slide was taken during one of the actual races. I watched three of the races on Jubilee III. This is the captain of the Jubilee III which is a motor sailor of 70 tons. It cost $4,000 a week to charter it. Here's some of the boats out on the race course. This was the Coast Guard Eagle. This is a Navy boat, and this is the Provincetown ferry, which was listing like this from all the people on board all the way around the course. Some guys go in style. Notice the helicopter on the after deck. Some can't go in style. This little guy right here in his 12 foot sail boat was 15 miles offshore. See how close we were to the other boats here. Here we are again trying to go to a mark, so we can see the boats going around it. It was just sheer bedlom, so after awhile we just stopped and drifted along with the pack.

This slide shows Australia won this race and soe pictures of it, and here she is coming back to Newport Harbor. She flew the big Australian flag with the Kangaroo on it, at the bow. The young lady on my left in this slide was my playmate for the voyage, I mean my shipmate for the voyage. These young ladies in this slide on board the Jubilee III were married to crew members on the Australia II. They were trying to raise the kangaroo flag and we were trying to keep it down.

It has been very interesting and enjoyable working in Newport Harbor and there is still a lot of activity and a lot of development going on there, however, I'm sure that no matter how much development there is, they'll never be able to change this beautiful sunset view over Fort Adams at the entrance of the harbor.

If anyone has any questions I'll be happy to try to answer them.

MR. SMITH: The next speaker is Michael Trawle who will address the subject of Advace Maintenance Dredging to Reduce Frequency and Cost.

ADVANCE MAINTENANCE DREDGING TO REDUCE FREQUENCY AND COST

BACKGROUN

MR. TRAWLE: One of the Corps of Engineers responsibilities is that of improving and maintaining navigation channels and harbors. In recent years, the cost of maintenance dredging in estuaries has grown rapidly because of such factors as increased environmental awareness, diminishing availability of cost-efficient disposal sites, and rising labor and dredging plant costs. In view of these continually rising maintenance dredging costs, any equipment, operation procedures or methodology that enhances the cost effectiveness of dredging should be utilized to full advantage.

DEFINITION

Advance mtaintenance dredging is a practice in which the channel reach is deepened (or sometimes widened) to allow a reduced dredging frequency or to improve project quality. Project quality refers to the percent of time in which a navigation

channel remains at project dimensions between dredging activity. Figure 1 shows a typical channel cross section designed with no advance maintenance. The allowable dredging tolerance (usually 1 or 2 feet) is provided for dredging inaccuracies. Figure 2 shows the same channel cross section designed with provisions for advance maintenance as overdepth dredging. Although not as common as overdepth dredging, advance maintenance as overwidth dredging is practiced, particularly in entrance or approach channels (Figure 3 - See Appendix).

DISCUSSION

Regarding the use of advance maintenance, Engineer Regulation 1130-2-307, paragraphs 9a, b, c, and d, of the Department of Army, Office of the Chief of Engineers, states:

"a. It is the policy with respect to authorized navigation projects to have full project dimensions maintained where feasible and justified. To avoid frequent redredging in order to maintain full project depths, overdepth dredging should be performed in critical, fast shoaling areas to the extent that it results in the least overall cost. Such additional dredging is exclusive of and beyond the allowable overdepth to cmpensate for dredging inaccuracies.

"b. The foregoing pertains not only to projects on which dredging operations are relatively continuouls throughout the year, but also to those projects on which dredging is performed periodically and by application of this additional dredging principle dredging intervals could be extended with attendant savings or justified needs of commerce can be satisfied.

"c. In the accomplishment of new work dredging, additional overdepth should be performed in those areas in which it is planned to provide additional maintenance dredging depth in accordance with a and be above.

"d. Division Engineers are hereby authorized to approve additional overdepth for new work and subsequent maintenance in conformane with the above stated policy.

Figure 4 (See Appendix) illustrates the advantage of advance maitnenance from a project quality standpoint. With advance maintenance, the deposited material does not result in loss of project depth until the storage volume provided by advance maintenance has been filled. Ideally, the use of advance maintenance will accomplish two goals: (1) to reduce dredging frequency and (2) to improve project quality (Figure 5 - see Appendix). In most cases, however, accomplishing only one of these goals by advance maintenance, either improving project quality or reducing dredging frequency can be considered as an effective aplication of advance maintenance.

A key factor to be considered in the evaluation of any channel for advance maintenance potential is the depth-shaling relation. If the channel shoaling rate increases severely as depth increases, then the effectiveness of advance maintenance is hampered in that the benefits as described above must be weighed against the need to dredge and dispose of increased amount of sediment annually. If, however, the channel shoaling rate only slightly increases or remains unchanged as depth increases, then advance maintenance can be very effective in that there is very

little or no additional volume of sediment caused by advance maintenance to dredge and dispose of.

A second factor affecting advance maintenance potential is the type of material beyond the project prism which must be excavated initially to provide for advance maintenance. If the material cannot be removed by normal dredging plant such as hydraulic suction or clamshell dredges, but requires other more expensive techniques such as blasting, then advance maintenance must not be cost effective because of the high initial cost to excavate. Also other bottom conditions such as the existance of tunnels, buried pipelines, or buried cables across a channel may eliminate the possibility of advance maintenance dredging.

The present Corps use of the overdepth form of advance maintenance in coastal and estuarine environments includes aout 300 navigation projects. The amount of advance maintenance varies from 1 to 8 feet with 17 pecent being 1 foot, 52 percent being 2 feet, 15 percent being 3 feet, 9 percent being 4 feet, 3 percent being 5 feet, 3 percent being 6 feet, and 1 percent being 8 feet. The Charleston, Galveston, Mobile, New Orleans, Norfolk, and Portalnd Districts are Districts which use the overdepth form of advance maintenance the most, accounting for 88 percent of the total advance maintenance projects.

The Corps use of overwidth dredging as advance maintenance is not a well defined practice at this time. Te procedure to obtain authorization for the overwidth form of advance maintenance, unlike the procedure for overdepth dredging, is frequently unclear. Often overwidth dredging is included as a project design feature and is therefore part of the project authorization. In other cases, overwidth dredging has been authorized by simply using the same procedure that applies for overdepth dredging, even though the E. R. 1130-2-307 only mentions overdepth dredging. In any case the fact that the authorization procedure for the overwidth form of advance maintenance is unclear probably accounts at least partially for its sparse use in navigation projects.

Selected projects which have in the past used or currently use overwidth dredging are being evaluated for effectiveness as part of the advance maintenance dredging work unit under the Investigation of Operations and Maintenance (IOMT) Program. These projects include Lynnhaven Inlet entrance channel, Virginia; the Pascagoula Harbor entrance channel, Mississippi; the Big Foot Sough channel in Silver Lake Harbor, North Carolina; and the Morehead City Harbor entrance channel, North Carolina, and the Coquille River entrance channel, Oregon.

Two Examples of Effective Advance Maintenance Projects

Shipyard River Channel, South Carolina

The Shipyard River is a saltwater tidal tributary of Charleston Harbor, South Carolina (Figure 6 - See Appendix). From its source, the river flows southerly about 3 miles and empties into Cooper River about three-fourths of a mile above Drum Island. Current velocities in Shipyard River are low, and the mean tide range is about 5 feet. Material deposited in this river is predominantly clay.

The Shipyard River navigation project, constructed in 1951, requires a 30-foot depth configured as shown in Figure 6 (See Appendix) Advance maintenance from 4 to 6 feet has been

included in maintenance dredging from 1961 to the present. The following tabulation summarizes the shoaling volumes and dredging intervals with and without advance maintenance.

Period	Project Depth	Advance Maintenance	Average Dredging Interval	Average Annual Maintenance Dredging
1951 to 1961	30 ft	0 ft	9.1 months	539,000 cu yd
1962 to 1977	30 ft	4-6 ft	12.6 months	448,000 cu yd

As can be seen, even though the dredged depth increased 4 to 6 feet from advance maintenance, the rate of shaling actually decreased. The required dredging interval increased from 9 to 13 months, thus reducing mobilication/demobilization costs signficantly and also improving project quality.

Coos Bay, Mile 12 to 15

Coos Bay, located on the Oregon coast about 200 miles south of the entrance of the Columbia River and 445 miles north of San Francisco Bay, is rather coplex with 30 tributaries feeding the bay. The largest of these tributaries is the Coos River, which has an average freshwater discharge of 2,200 cfs. Sediment transport to the estuary is estimated to average 72,000 tons annually. The estuary is generally classified by salinity distribution as partly to well mixed.

The upper portion of the Coos Bay project, Mile 12 to 15, is shown in Figure 7 (See Appendix). The project depth of Mile 12 to 15 from 1952 to 1976 was 30 feet. From 1952 to 1962, no advance maintenance was used on the project. However, from 1962 to 1976, 3 to 5 feet of advance maintenance was used at Mile 12 to 15. The following tabulation summarizes the shoaling volumes and dredging intervals with and without advance maintenance.

Period	Project Depth	Advance Maintenance	Average Dredging Interval	Average Annual Maintenance Dredging
1955 to 1961	30 ft	0 ft	22.2 months	470,000 cu yd
1962 to 1974	30 ft	3-5 ft	45.7 months	420,000 cu yd

As can be seen, even though the dredged depth increased 3 to 5 feet from advance maintenance, the rate of shaling decreased slightly. Furthermove, the required dredging frequency changed from once every other year to once every four years, a tremendous improvement from the mobilization/demobilization standpoint.

SUMMARY

Advance maintenance is a procedure that in many cases has the potential of reducing overall maintenance dredging costs by reducing mobilization/demobilization costs and at the same time iproving project quality. The two examples of advance maintenance given in this paper represent effective advance maintenance projects in that both dredging frequencies were reduced and project qualities improved without any increase in shaling rates. In many cases, the addition of advance maintenance to a project causes some increase in the amount of material trapped, which means that the increased shaling rate must be weighed against the reduction in dredging frequency or improved projec quality to determine the worth of advance maintenance. Since the potential benefits can be substantial, advance maintenance should be given consideration in any navigation channel requiring peiodic maintenance.

(Dinner recess.)

APPENDIX

WEDNESDAY, OCTOBER 31, 1984

8:00 a.m.

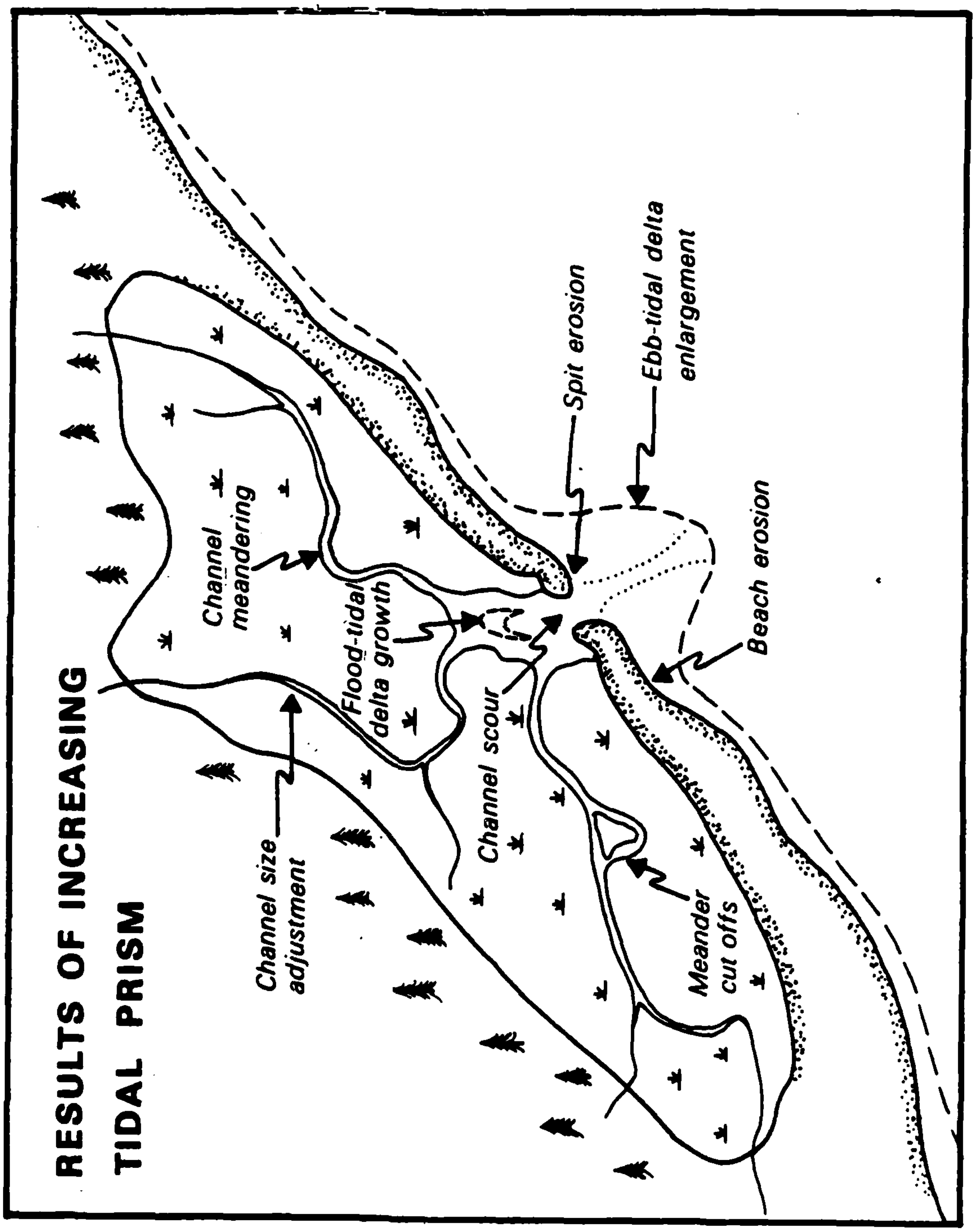

RESULTS OF INCREASING TIDAL PRISM
Channel meandering
Flood-tidal delta growth
Channel scour
Channel size adjustment
Meander cut offs
Spit erosion
Ebb-tidal delta enlargement
Beach erosion

FIGURE 1

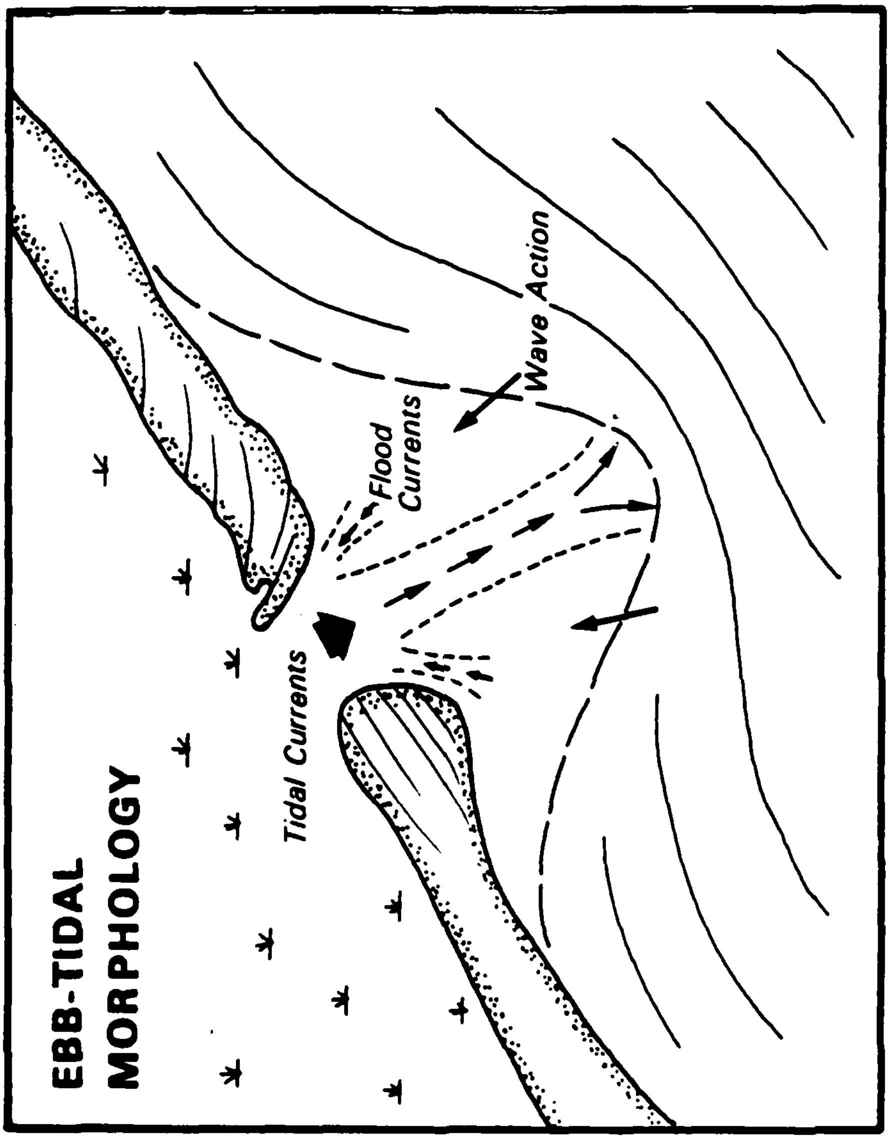
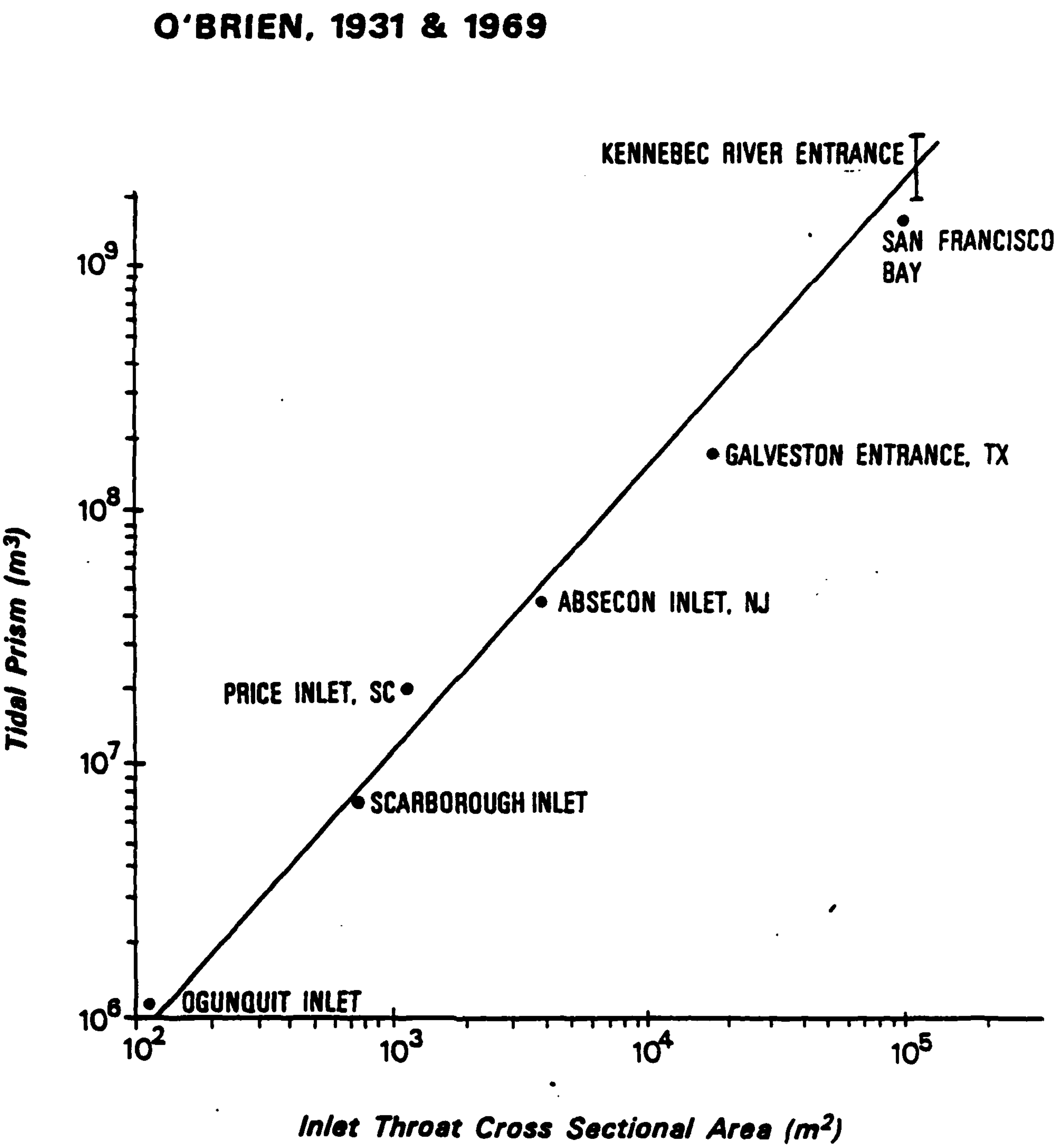

EBB-TIDAL
MORPHOLOGY
Tidal Currents
Flood
Currents
Wave Action

FIGURE 2

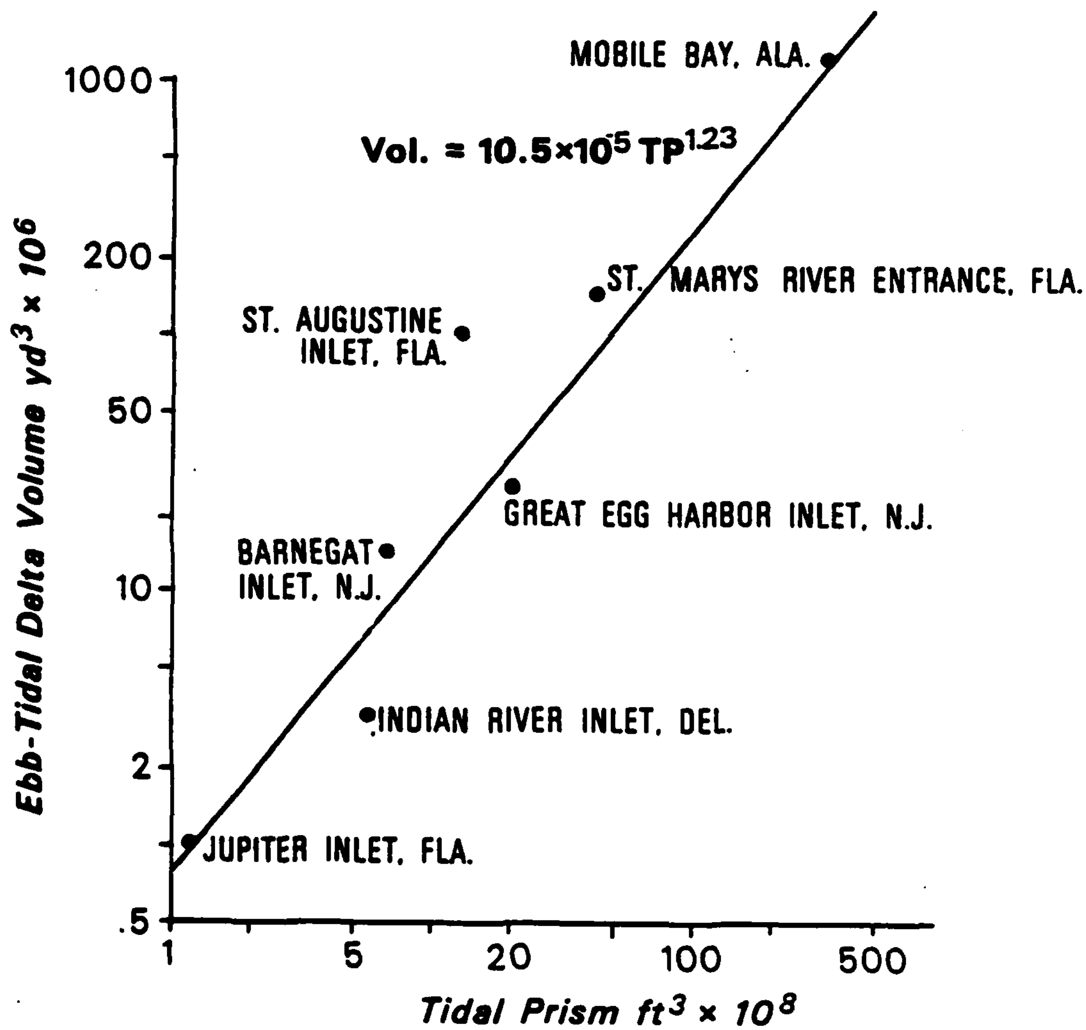


O'BRIEN, 1931 & 1969
KENNEBEC RIVER ENTRANCE
SAN FRANCISCO BAY
GALVESTON ENTRANCE, TX
ABSECON INLET, NJ
PRICE INLET, SC
SCARBOROUGH INLET
OGUNQUIT INLET
Tidal Prism (m3)
Inlet Throat Cross Sectional Area (m2)
10^6
10^7
10^8
10^9
10^2
10^3
10^4
10^5

FIGURE 3

TIDAL PRISM - EBB-TIDAL DELTA VOLUME

(Relationship for Moderately Exposed Coasts)



Criteria for Moderately Exposed Coasts: $H^2 T^2 = 30-300$

Maine Coast: $(2)^2(5)^2 = 100$

FIGURE 4

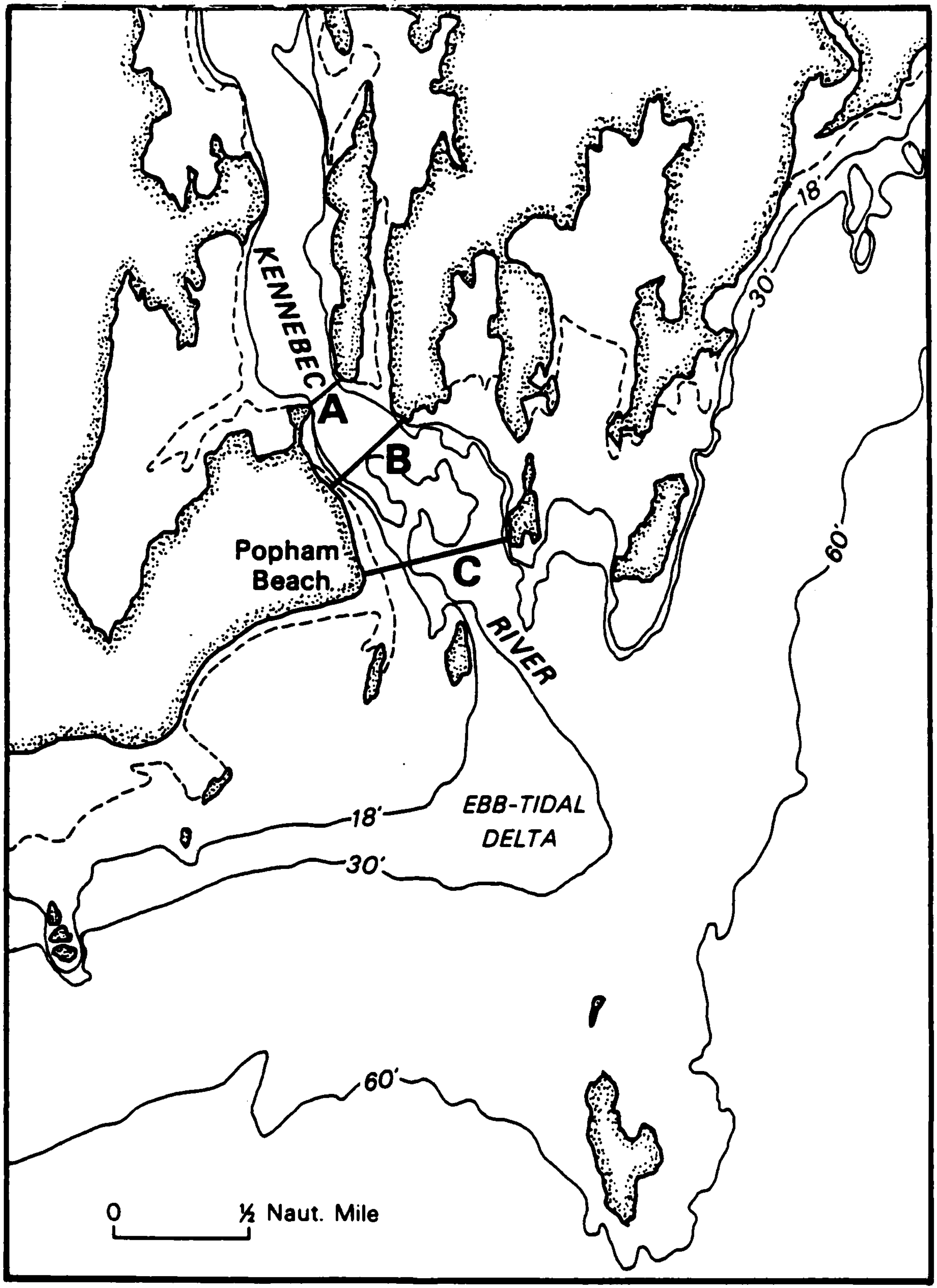
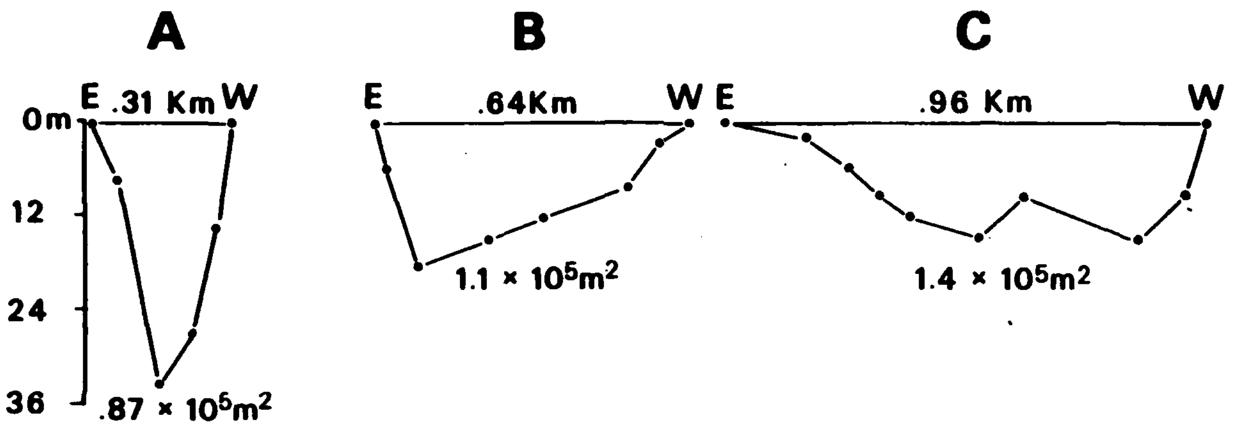

KENNEBEC
A
B
C
Popham Beach
RIVER
EBB-TIDAL DELTA
18'
30'
60'
30
18'
60'
0
½ Naut. Mile

FIGURE 5



Ave. Cross Sectional Area = $1.1 \times 10^5 m^2$

Using Jarretts Equation $A = 2.26 \times 10^{-5}\ TP^{1.07}$

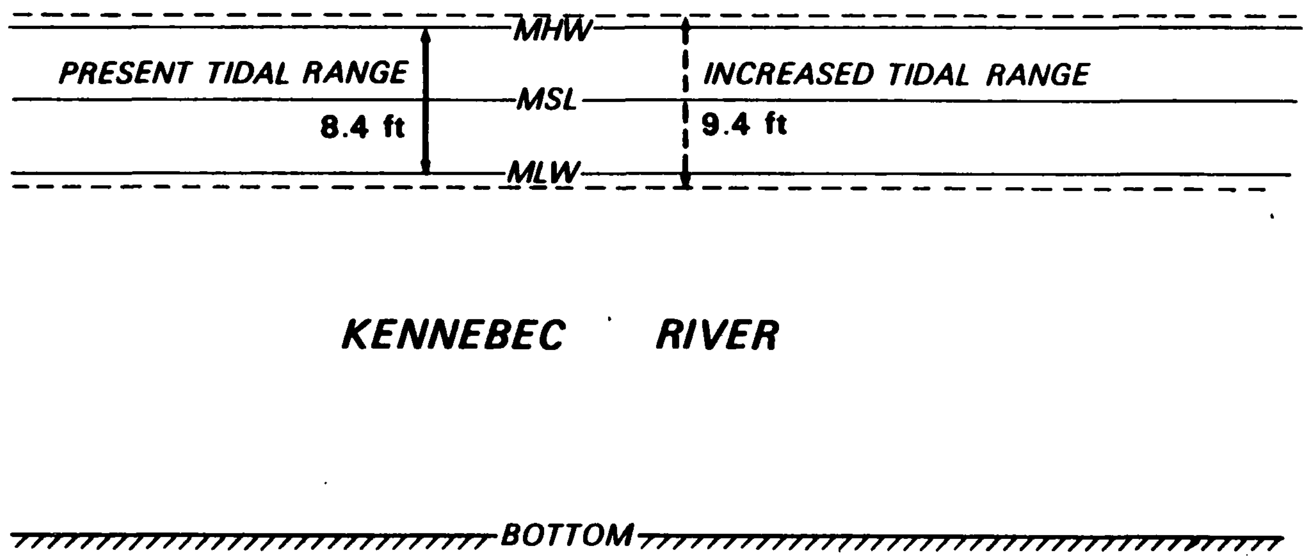
Tidal Prism = $1.13 \times 10^9 m^3$

Using Walton and Adams Equation $Vol = 10.5 \times 10^{-5}\ TP^{1.23}$

Predicted Vol. of Ebb-Tidal Delta = $8.7 \times 10^8 m^3$

Calculated Vol. from Bathymetric Data = $1.06 \times 10^9 m^3$

FIGURE 6



Considering the Attenuation of the Tidal Wave
Tidal Prism will Increase 5 - 10%

Increase in Ebb-Tidal Volume = $5.7 \times 10^7 m^3$
(using conservative estimate of TP increase of 5%)

FIGURE 7

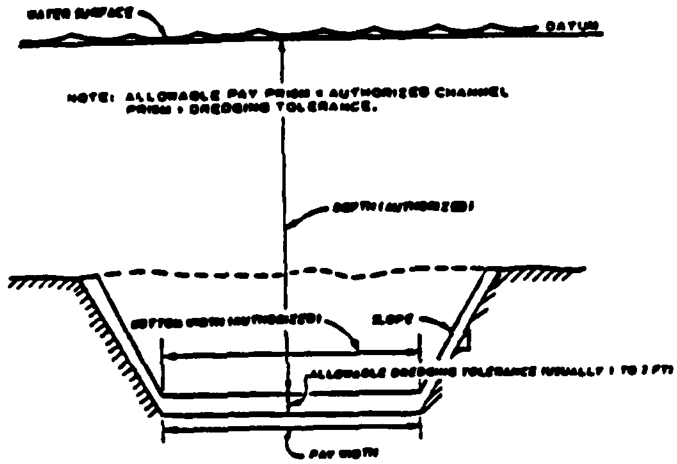


Figure 1. Dredged channel cross section without advance maintenance

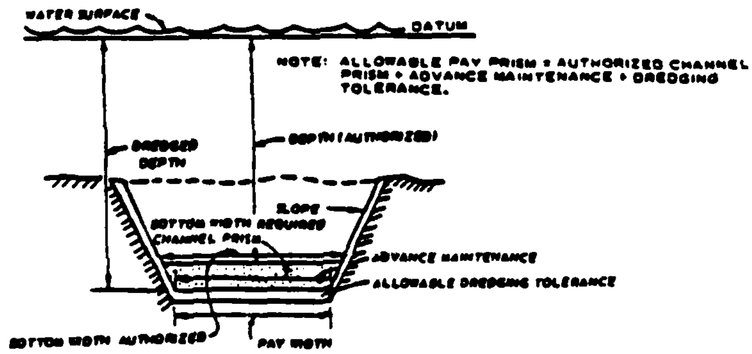


Figure 2. Dredged channel cross section with advance maintenance

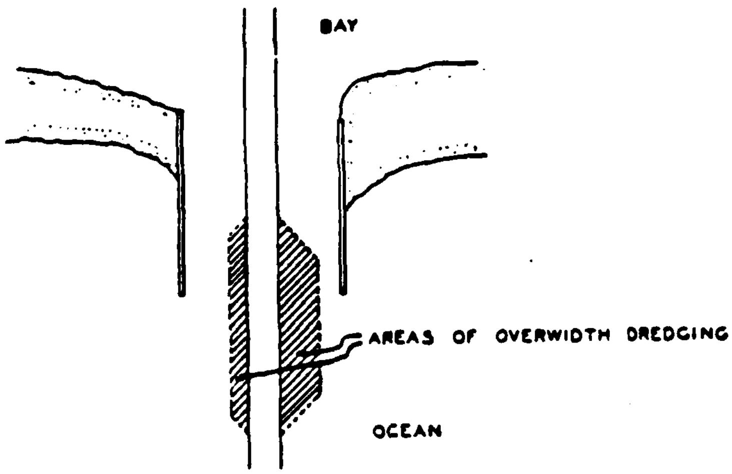


Figure 3. Advance maintenance as overwidth dredging

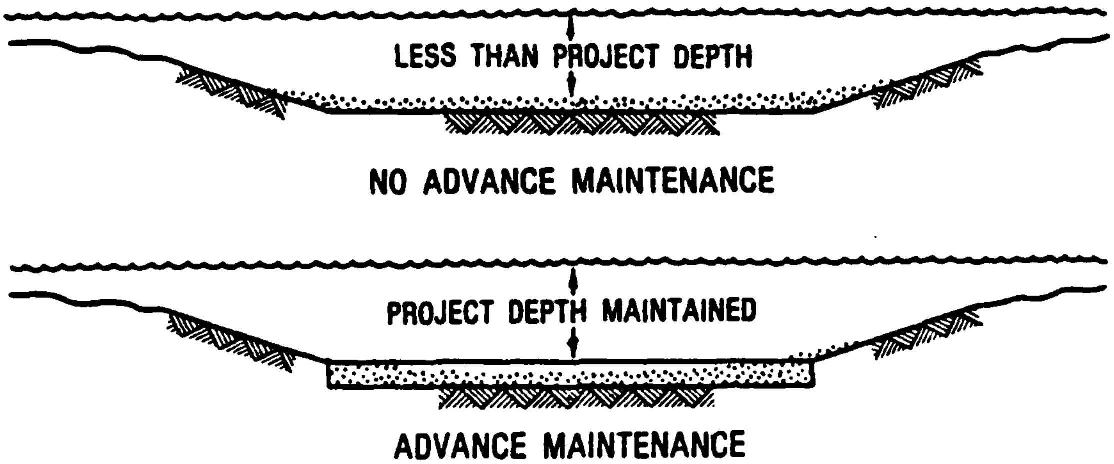


Figure 4. Cross sections of navigation channel shoaling with and without advance maintenance

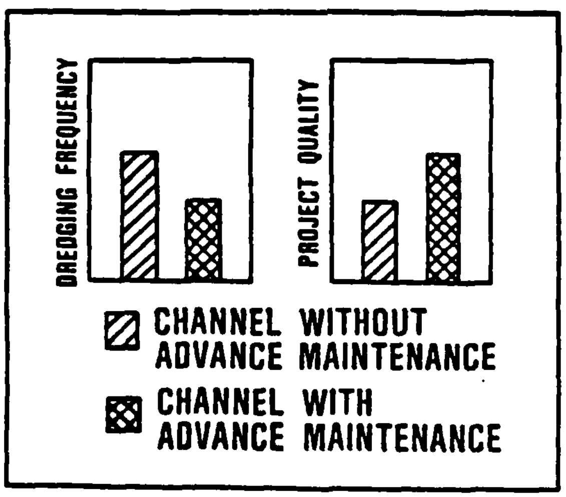


Figure 5. Potential benefits from advance maintenance

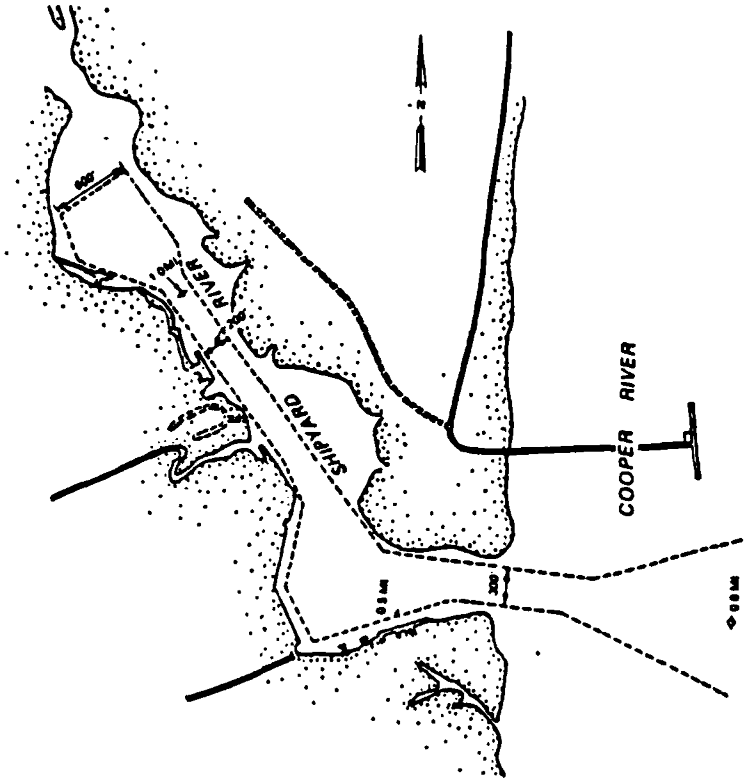


Figure 6. Shipyard River Project, South Carolina

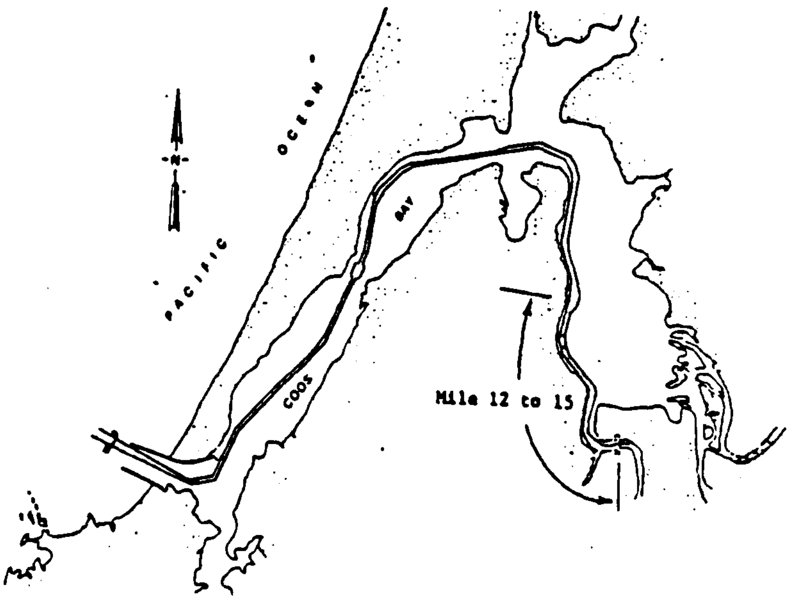


Figure 7. Coos Bay Channel, Mile 12 to 15

WEDNESDAY, OCTOBER 31, 1984

7:30 p.m.

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APPENDIX

EVENING SESSION

MR. BRUHA: Can we sit down and get started. They'll still be wandering in most of the evening.

I would like to see this handled a little bit differently tonight. Rather than me being up here introducing everybody, why don't we just go by the scheduled and let the person that's giving the presentation handle the presentation and then my questions afterwards. And then following speaker on the program, just automatically walk up and introduce himself and mention what's he's going to talk about. It will save us a little time as well. So if that's okay with you, I would like to introduce though Dr. Spaulding.

A NUMERICAL MODELING CHARACTERIZATION OF THE ANNUAL 3-DIMENSIONAL CIRCULATION IN THE GEORGES BANK-GULF OF MAINE REGION

MR. SPAULDING: My name is Malcolm Spaulding, and I'm a faculty member at the University of Rhode Island, Department of Ocean Engineering. In addition I work for a small consulting engineering firm in Wakefield, Rhode Island called Applied Science Associates, Inc.

The topic of my talk is a numerical modeling characterization of the annual 3-dimensional circulation in the Georges Bank-Gulf of Maine area. I'm specifically talking about the long-term circulation dynamics as opposed to short term. I'm interested in seasonal kinds of circulation in the area. This particular effort was funded by the Minerals Management Service in relationship to offshore petroleum development, and the impacts of oil spills on commercial fisheries. So the focus in this effort is to look at the long-term seasonal circulations patterns in the area.

The presentation I'm going to give is outlined here. Essentially I'm going to give a little introduction about the problem, the objective of the study, the particular approach that we have chosen for this effort, a very, very brief description of the modeling methodology and some examples of how we drove the model for the four forcing mechanisms that are of interest in this area, and finally, I will show you some pictures of the seasonal predicted circulation pattern, and then end with some conclusions.

The objective as I just suggested was to determine the role of tides, wind, longshore pressure gradients and density forcing in driving the 3-dimensional seasonal circulation patterns in the study area, and looking at that from a numerical modeling methodology as opposed to, say, a data analysis procedure.

The study area, I'm sure you're all familiar with, Georges Bank/Gulf of Maine/Bay of Fundy area. The focus of this particular study was on the offshore lease tracks which are located along the southern flanks of the Georges Bank area. So the primary focus of the effort is looking at the Georges Bank gyre and the Gulf of Maine gyre associated with it, rather than being focused specifically on the Bay of Fundy or some other area.

For those of you who know anything about the circulation dynamics of this particular area, particularly the

long-term seasonal circulation patterns, you have probably seen this plot not less than a couple of hundred times. This is the famous plot by Bigelow produced in his 1927 work on the circulation in that area, and it's his estimate of the surface residual circulation pattern for a typical summer case. This picture often appears in papers and is referenced in every paper I've ever seen on Georges Bank circulation.

The question is what drives this circulation? Why are the patterns like this? The question is what's happened since Bigelow did his early work? Well, Bumpus and Lauzier in 1965 did an analysis of the drifter data and the current meter observations as of that time, and came up with the seasonal variability to the pattern. I show you here the spring circulation patterns. These are surface current patterns.

And the point to be made here is that we essentially have two circulation gyres. We have one a clockwise circulation gyre around Georges Bank, and then a counter clockwise circulation gyre in the Gulf of Maine.

If we now go on and look at the summer pattern, we see a strengthening of the gyre on Georges Bank, still the presence of the circulation gyre in the Gulf of Maine.

If we go ahead into the fall season, we see that the Georges Bank gyre has started to disappear, at least from the surface signature, while the Gulf of Maine gyre is present but weak. And then finally into the fall season, where the Georges Bank gyre has all but disappeared, and we have a still present but weak Gulf of Maine gyre.

So that the pattern based on Bumpus and Lauzier's analysis of all of the drifter observations suggest that there is a gyre formed at the surface circulation patterns in the spring, the gyre strengthens then into the summer, weakens into the fall, almost disappears in the winter, and then reappears in the spring. This obviously has important implications for the long-term circulation for the area and for the residence times of material that may be discharge into that area, either naturally or by some man-made discharge.

There's also been some recent current meter analysis work, observations taken by the Minerals Management Service contractors, namely EG&G, and the U.S. Geological Survey for the Georges Bank/Gulf of Maine areas, particularly Georges Bank. These show the presence of a strong gyre in that area. Currents on the order of 20, 25 or 30 cm/sec on the northern flank, weakening on the northeast peak, and then return flows along the shelf break area. These insitu observations over depth show this same gyre like feature and present over long periods of time.

Now, the approached that we have chosen for these particular simulations is, in order not to make this problem unduly complicated and be able to complete the simulations in some reasonable period of time, to perform simulations for each forcing function independently, with the exception of the tidal influence on the wind induced flows, and recreated the 3-dimensional patterns for each. And then we've made the assumption that linear super-position is an acceptable way to put those current patterns back together. That assumption is based on the fact that there is minimal interaction between the various forcing mechanisms.

That appears to be a reasonable first approximation

with the exception of the wind's influence, i.e. the tide wind coupling. In that particular case we've run the model with both of those and then subtracted the tide from that analysis.

And so the total current is composed of the vector addition of the tidal currents, the wind currents, the longshore pressure gradient currents, and the density induced flows. That's an important simplification of the problem, early on, to allow us to attack it in some reasonable amount of computer time.

No true modeler would go on without showing the equations he worked with. No true modeler would spend a lot of time talking about those equations with people who were not to excited about them. What we're essentially doing is solving the 3-dimensional conservation of mass and momentum equations subject to quadratic stress at the bottom and at the free surface, which performs coordinate transformation in order to map the variable topography on to a uniform plane. Because we have transformed the systems, we have some transformation operators that we applied to the equations. These transformation operators complicate the equations slightly, but it turns out that it is numerically convenient to do that.

I won't talk about the numerical technique in detail, but we solved it by Legendre polynomial approximation in the vertical, and an explicit finite difference approximation in the horizontal.

We will talk about the model application to the Georges Bank/Gulf of Maine region, tidal forcing, longshore pressure gradient forcing, atmospheric forcing and density forcing. I want to talk about the tide a little bit individually because that's of particular interest, and then I'll go on and show you the composite of these pictures and not talk about the individual processes.

The grid system we selected for the area was 25 kilometer square grid. The grid orientation and the grid geometry are shown here. The boundary conditions for the outside area were determined from Schwederski's deep ocean tidal model. The outside boundary of the model domain is beyond the continental shelf break. The boundaries in the cross shelf direction have been located to minimize problems related to specification of the open boundaries.

Here's a detailed picture of the bathymetry that's used in the area. What you see is essentially the shallow feature which is Georges Bank. There is the northeast channel, southeast channel, the deep basin of the Gulf of Maine, and then shallowing up into the Bay of Fundy area. As you can see that's a fairly coarse representation of the study area, and I'll say a few more words about that in a minute.

If we run the tidal simulation for a very long period of time and then take the time average of those, this is the predicted long-term, tidally-averaged or tidally-induced flow field that is generated by the presence of the tide. And what you see here are two major gyre features, One gyre here and one here. This gyre is due to the shallow Georges Bank region. The second gyre that you can see a portion of here is due to the Nantucket shoals region, and then this strong flow around Nova Scotia in this area here.

That picture agrees with the available observations

in terms of the patterns that are there. The detail is not very exciting if you look at that. And let me show you what happens if you increase the model resolution by a factor of four.

The new bathymetry looks like this, and you can still pick out the same features. The tidal currents are quite startling. These are the tidal current roses or ellipses really, and the arrows show the direction of rotation. You can see these stations are in essentially deep water, so the tidal currents are very small. As the tide propogates over Georges Bank. The tidal currents increase substantially. On the other side of Georges Bank they go back down, and then as you come close to shore features or up into the Bay of Fundy, you get some rectilinear features.

The question is how good does the model compared to observations? This is from that long-term data set that I showed earlier, a comparison of our model predictions for the tidal current ellipses to the observations. Those are all the observations that were taken in that long-term current measurement program which lasted over a year.

As you can see we do a reasonable job of reproducing not only the magnitudes but the orientation of those tidal ellipses. The worst errors are at this particular station here, and the bathymetry there is under-resolved even at the 6 and a quarter kilometer grid spacing that we have.

Now, if we do the same calculation that we did before and look at long-term tidally induced residuals, you can take a look at that and you can see an incredible richness in the structure of the residual flow patterns. You can see the presence of the two gyres here. They are considerably more complex. The Georges Bank gyre is located here. You can see considerable more structure as well as some unusual features, seemingly that the currents are turning almost at right angles at a particular location. It turns out to be due to the bathymetric features in that area. There is considerably more complexity in the circulation, the tidally induced circulation, around the end of Nova Scotia.

If you take this particular plot and compare this to Dave Greenberg's work on a point-by-point comparison, the agreement is startling, considering that we started with different models, different bathymetry, different topography, different boundary conditions. In terms of patterns, you can't tell the difference. In terms of absolute numbers, they differ on the order of a centimeter a second, typically.

Okay, let me go on to my 3-D simulations now at the 25 kilometer grid. I'm going to go back to my original talk, and I'm going to show you some individual cases.

This is the influence of a longshore pressure gradient imposed on the offshore boundary. The pressure gradient is impressed by the North Atlantic and the currents associated with the North Atlantic in terms of moving the ring systems down along the coast. And this impressed gradient on the area leads to a longshore induced transport. You can see some transport into the Gulf of Maine and then back out of the northeast channel.

In order to run the model for the density induced flows, the question arises as to how one specifies the salinity and temperature field for that model simulation. What we did is

we went to the National Ocean Data Center and collected all of the observations they had from the late 1800s, early 1900s up to the present, and then went ahead and tried to determine a consistent time period over which observations exist to do the modeling.

Unfortunately you can see we have picked out the four best seasons here, and even with the four best seasons, you can see that the sampling is extremely sparse over this particular area. You can get a sense why, if you're interested in looking at density induced flows, you can't go to resolution of much more than 25 kilometers if you expect to have a substantial resolution on the density fields.

What I'll do now is I'll show the seasonal circulation patterns. I'm going to concentrate on the surface ones in the interest of time and in the interest that those are where the key observations are. I won't talk about the bottom patterns unless someone is particularly driven or particularly interested in them.

Starting in the spring, these are the combination of the vectorial additions of all four of those forcing functions in terms of their response. What we in general see is that there is a transport down the shelf along the shelf break. There's the presence of the Georges Bank gyre and that's a clockwise gyre. There's the presence of a counterclockwise gyre in the Gulf of Maine, just as has been observed in the drifter studies of both Bigelow and Bumpus and Lauzier's charts, and you can see a gyre like circulation on the Nantucket shoals.

If we go into the summer season, you can see that the pattern is substantially the same, but what's happened is there is an enhancement of the Georges Bank gyre in terms of both its strength but not in terms of its size. We see more flow coming up the southeast channel to close the gyre.

As we go into the winter or as we go into the fall, what happens is the winds pick up, the wind direction shifts from the southwest in the summer to the west and heads up into the northwest in the winter and fall seasons, and the magnitude of the winds pick up so that at the surface, the currents are more subjected to wind induced flows. So what happens is we're essentially seeing that gyre like feature at the surface induced by the Georges Bank circulation gyre start to disappear. The currents at the surface give the transports offshore.

And finally in the winter, you can see an additional destruction of the gyre like feature at the surface, and material being transported offshore and then eventually along shore. However, there is the Gulf of Maine gyre, a remnant of that is still left, and that's due to the strong flows here on the Scotian shelf.

Those circulation features, if I look at that in terms of a qualitative sense, give a reasonable representation of the circulation dynamics in that area. If I look at them quantitatively, I get reasonable representation at a couple of locations and unreasonable representation at a couple of other locations. If I look at residence time on Georges Bank from this model prediction and compare it to drifter studies, they are within several days, on the order of five or ten days of the observations for that area. In terms of residence times of 60 days, the model might predict 65 days or around that order.

Obviously since the model is three dimensional, we have seasonal predictions four for the bottom flows. Those are much more confused and there is much less data to compare to, but those observations are available or those predictions are available, and they tell us something about the dynamics of the water balance there.

In conclusion, this full 3-dimensional model has successfully reproduced the broad scale features of the observed long-term surface seasonal circulation pattern. And I want to emphasize that these are broad scale features, i.e. the model resolution is too coarse. We're looking at the patterns more than the absolute numbers, because of the resolution problem.

The tide residual and density are dominant forces driving the Georges Bank gyre. Those two forcing mechanisms add together to strengthen the gyre. The Gulf of Maine gyre is driven mainly by the tidal residual and the longshore pressure gradient induced flows, those two also adding together to produce that gyre like feature in the Gulf of Maine.

The surface wind induced flows dominate surface flow patterns in the winter and the fall. So when the surface winds pick up in the fall and winter and switch from the southwest up to the northwest, they essentially dominate the surface flow patterns.

The present model resolution of 25 kilometers, as I've shown you by a simple application for the tidal case, is really too coarse to accurately predict the amplitudes and the spatial structure of the flow, and that was clearly demonstrated by those model predictions in terms of increasing the resolution locally. The reason we choose not to go to an increased resolution was that the density data that we had, namely the salinity and temperature data, that was available was not adequate to support the increased resolution for the density induced flow processes.

We also noted that the approximation we used for the open boundary condition for the wind induced simulations assumed that the shelf was infinite in length. It appears in terms of the response of the model that that is not the case for the model domain that we had. Some other approximation is certainly more appropriate. The folks at Bedford, Dave and some of his colleagues, are looking at that particular problem.

With that, I'll conclude my talk and I'll be happy to answer any questions that you may have.

MR. BAER: Can you put up the bottom flow?

MR. SPAULDING: There is a little key in the upper left-hand corner, and it's all bottom wind drift. There's the winter. There's the winter, fall, summer.

MR. BAER: When you say bottom winter, what thickness is the layer of resolution?

MR. SPAULDING: The model is continuous in the vertical. So we essentially have continuous functions in terms of the Legendre polynomials that are used to represent the vertical structure. They are done in a transformed space. So the profiles are essentially continuous. For these predictions or for these plots, what we've done is we've taken the values that are integrated over the bottom 10 meters and the top 10 meters. So if you will, this picture is rubber sheeted to conform to 10 meters

off the bottom as opposed to some constant level.

So that's why, for instance, you see circulation everywhere as opposed to seeing it in some deep kettle area, and that's because of this rubber sheeting. Rubber sheeting means that you distort the grid. Anyway it's a numerical technique in order to be able to follow the circulation with the same relative resolution in all the grid points. Any other questions?

(No response.)

APPLICATIONS OF REMOTE SENSING TECHNIQUES TO SHORE AND BEACH EROSION.

MR. GATTO: My name is Larry Gatto, and I'm from CRREL. I'll explain the meaning of that acronym in a moment.

I'd like to clarify a few things. When Tom asked me for a title of this presentation, I gave him the one listed in the agenda, but it does not cover the total picture of what I'd like to discuss with you for a few minutes tonight. Although I will be mentioning some of the remote sensing techniques that we use during our coastal studies, I'd like to broaden the topic to include that coastal work we've done at CRREL without remote sensing techniques.

Secondly, I've got a handout which I'll make available on one of the tables when the evening session is over. The last two pages of that handout show some of the people who are involved in coastal work at CCREL. So this is by no means a discussion of my work. It's a discussion of that of many people. If you want to get in touch with them about the details of their work, you can get their names from that list.

What is CRREL? It's the Army's Cold Regions Research and Engineering Laboratory. It's located in Hanover, New Hampshire. It has a main laboratory building, an ice engineering facility, and a building not shown on this picture located here that is the Frost Effects Research Facility (FERF).

FERF is designed for the study of the effects of frozen ground and ice-rich permafrost on engineering structures. The purpose of the Ice Engineering Facility is for modelling ice processes on rivers, lakes and resvoirs or along the coast. We've got a model now of Casanovia Creek which is in the Buffalo District of the Corps of Engineers. That model is for testing the best ice retention structure to reduce ice jam flooding on the Creek.

CCREL's research on snow, ice and frozen ground is applied to military and civil works functions of the Corps and also to other governmental agencies and private industry that work in places where ice, snow and permafrost is a large environmental factor must be dealt with. I'll be discussing some of the civil works projects this evening.

The four general areas I'll address are surface circulation, sea ice distribution, wetland distribution, and coastal erosion. Most of the work that we do is obviously in northern areas or in the south polar regions, so remote sensing is a very convenient way to get information about the environment of these areas without being on the ground. We use remote sensing techniques as data gathering tools which provide useful

information that would be expensive to collect in other ways.

This is a picture of SPOT simulation imagery. SPOT is an acronym for a French satellite to be launched in '85. It's designed to provide stereo, panchromatic imagery, and multispectral imagery. This picture shows a diked dredge material disposal site near Baltimore. CRREL is mapping circulation patterns in the area to determine how useful SPOT imagery will be in surface circulation studies and in tracing the potential path of sediment coming from disposal sites.

We've done similar work in Cook Inlet in south central Alaska. This is a LANDSAT picture of the Inlet. Anchorage is located here. This is first year ice on the inlet. We used it and suspended sediment as tracers of surface circulation patterns. We could infer from the patterns on the imagery what the surface water circulation was like. It turned out that remote sensing was a very convenient way to get a general idea of surface circulation patterns in this large body of water without having to do extensive ship surveys.

This picture shows Kachemak Bay on the southeast side of Cook Inlet. Frazil pans of ice are shown here at the head of the bay and ice stretches along the north side towards it's confluence with Cook Inlet. The purpose of the slide is to again illustrate how sea ice can be used for tracing surface circulation patterns.

The study of circulation in Kachemak Bay was done with the Alaska District, Corps of Engineers, to provide information for decisions on whether or not a hydropower project on Bradley Lake on the southern side of Kachemak Bay should be developed. Since winter fresh water runoff would be greater after the project than exists now, additional ice may be discharged into the Bay. We analyzed winter surface circulation patterns and ice movement in the bay using LANDSAT imagery to see, if additional ice were formed, would it move into the harbor area of Homer. There is concern about navigation problems that might be caused by additional ice.

Along with these studies of sea ice distribution, CCREL does extensive research on and modelling of sea ice characteristics and dynamics in the Beaufort Sea and Arctic Ocean. It's very expensive or impossible to get a ship out there to collect the data you need for ice studies. Satellite imagery and remote sensing techniques are very useful for this work.

This picture shows a LANDSAT image taken on the 19th of March, 1973, and three days later. It illustrates how rapidly the pack ice north of Barrow, Alaska, deforms and gives a view of where the pack ice moves. By analyzing repetitive imagery, one can trace the migration of the ice, and based on that data, model ice dynamics which is an on-going effort at CRREL. Much of this work has been done in cooperation with NASA, BLM and the offshore petroleum industry.

The third area for discussion is wetland distribution. I won't get into the particulars of this since most of you folks here are more aware of wetland types than I. As you know, color infrared and color photography are very useful in delineating wetland types.

As we've seen during many of the talks today, aerial photography is also very useful for analyzing changes in shoreline

geomorphology and for observing nearshore patterns of sediment movement. This picture shows the bank along the Beaufort Sea just east of Prudhoe Bay, Alaska. Soils here are very peaty and are underlain by ice-rich permafrost or permanently frozen ground. When this permafrost is heated, the ice in it melts and adds to the normal bank erosion processes that occur. You get terrifically high erosion rates at many locations along the northern coast of Alaska. We've been investigating some of these processes and trying to get an idea of the variability in the rates along the coastline.

I've discussed ice several times. This picture shows one of the problems that it can cause in the coastal zone. Most of us have also seen at one time or another some type of structural damaged caused by ice forces. This slide shows an area near Sault Ste. Marie, Michigan, along the St. Marys River, and illustrates what can happen to shoreline structures. It looks like this building was knocked off its foundation by vertical ice forces. In addition, vertical forces can cause this type of ice jacking to docks. This slide is also on the St. Marys River at Johnson's Point, and it shows in graphic detail the amount of damage that can be done to structures.

Not only does ice damage structures, but also the banks. This is a picture of the southern shore of White Fish Bay on the southeastern side of Lake Superior. It was taken in March of 1979, and it shows ice that was pushed up the beach and over the bank by wind. There is about a 15 to 20 foot bank that the ice was driven over and into the backshore area, and caused considerable bank erosion and inland damage. This slide in May of that same year shows the vegetative damage and the general disruption the ice caused along this shoreline. There's very good historical evidence that this kind of ice push occurs frequently along the coast of Alaska.

These blue areas on this slide show some of the high potential petroleum producing areas offshore of Alaska. CRREL has been working with some oil companies to provide ice information for these areas. Oil development is a big reason for much of the offshore activity around Alaska.

This is a picture of a drilling island built in Mackenzie Bay in the eastern Beaufort Sea. CCREL has instrumented this man-made island to measure forces produced by the ice pack during the year.

It might surprise you to hear that not only is permafrost or permanently frozen ground located under land but it extends beyond the shoreline out under the ocean off northern Alaska. This slide shows the boundary between the ocean bottom that is not ice-bonded and areas where ice-cemented permafrost occurs. This is a major factor when you're going to build structures that have to be bedded in this material. if you don't know where the permafrost exists and you penetrate into it you start thawing the permafrost. This causes a very unstable condition for the structure. So, knowing where the permafrost exists and where it forms are very important.

This slide shows a small offshore island that is a migrating inland and, what we call, the permafrost bulb and its remnants that formed under the island. As the island migrates, the permafrost bulb indicates where the island was some years before,

and a new bulb forms in the new location of the island. So permafrost is a real problem when you're dealing with offshore construction in the Arctic.

This is a picture offshore of New Haven, Connecticut. CCREL is testing geophysical techniques that can be used to detect offshore permafrost. We're testing in the New Haven area because the difference between bedrock and sediment offshore is well defined. This graph shows how DC resistivity measurements correlate well with charts of subsea bedrock configuration. We feel encouraged that this technique may be useful in differentiating areas with ice-rich permafrost from areas where permafrost is absent. The idea is to test the technique in a convenient area nearby and then try it in Alaska.

We've also done some work for the Navy in designing and recommending the types of machines that could be used for subsea trenching and pipeline laying. This is just a schematic of what one machine might look like if someone wanted to try to do this in an area where there was ice and permafrost to deal with.

Finally, I'd like to close by saying that although CRREL has not done work in the area that we've been addressing over the last day and a half, the Gulf of Maine/Bay of Fundy, Dr. Larsen mentioned on the first day that it's not totally unlikely that there might be some possible ice problems created in the areas of the Bay of Fundy where blockages are built for the hydropower. Ice can occur off the northeast. We see it here in this LANDSAT picture of Cape Cod showing sea ice. Cape Cod Canal is here and the ice here.

So it may be that CRREL will become involved in some of the studies in the Bay of Fundy or along the Gulf of Maine.

I'd be happy to entertain any questions or comments.

(No response.)

TIDE GAGING BY PRESSURE SENSING MANOMETERS

MR. SOCOLOW: Good evening, ladies and gentlemen. My name is Roy Socolow. I'm with the U.S. Geological Survey, Water Resources Division. I'm a hydrologist, and my primary responsibility is measuring and quantifying stream flow in the state of Massachusetts.

We do this with some pretty sophisticated river stage measuring equipment. Most of you are familiar with the Fisher Porter analog digital recorder, and this punches a river stage on the punch tape. The other type to which I'll address my speech tonight is the pressure stage manometer. This instrument remotely senses pressure, water pressure on an orifice end out of which nitrogen gas has been bubbled. The pressure in the water area is remotely sensed and recorded by the Fisher Porter recorder. This pertains to the Roughans Point coastal flood protection study which Lee Butler addressed to earlier, and he told you pretty much the why's for the studies; I'm going to show you a little bit about the how's.

It refers to the Revere Beach just north of Boston, and we can focus in a little closer. Here we have the Roughans Point which he referred to, and I'll be showing some of the other areas where we placed tide gauges.

Of course, flooding is the big problem, and needs to be addressed and studied. Unfortunately in this area the Boston tide gauge just didn't provide enough data. So the Corps asked the USGS to use some of our water sensing techniques to collect more tide gauge data. Obviously this is a picture of some problems in the Roughans Point area, and hopefully after the study is concluded the COE will be able to eliminate or reduce these problems.

This is the flooded area around Roughans Point and possibly with increased tide data they will be able to provide either new or extensive seawalls to prevent such flooding.

We went out on some site selections earlier in the spring around March and we arrived at five sites to be gauged. One is down here at Roughans Point. Another is up just south of Lynn. These two are the open ocean gauges. We have three more gauges, one on the Saugus River at the Fox Hill Drawbridge, another on the Pines River at the Broad Sound Tuna Club, and a third one across the railroad bridge up here by Route 107 at the Atlantic Lobster site.

This is the Bay Marine Lobster up near Lynn. This is pretty much your standard stage recorder with a float that sits on the water, your standard Fisher Porter recorder inside. This is the Fox Hill Drawbridge where we placed one of our manometers. The beauty of the manometer is that once you have a stable place for the instrumentation, the tubing can be placed with good security along any part of the piling, any piers, bridge columns, anyplace that will not move. So it does provide good data if you can secure your tubing end.

This is the Broad Sound Tuna gauge, and here's the gauge house with the recorders inside. The end of the tubing extends all the way out past this boat. One of the advantages of this type of gauge is that you can run tubings several hundred feet. We have a stream gauge in western Massachusetts where we run the tubing 700 feet, and there are ways of adapting it to run even longer.

The Atlantic Lobster gauge is through the railroad bridge right here. This is the Pines River. This is the gauge house, very portable. It took one day to set up, and it's quite a good system. This is your Roughans Point area here. This is a rent-a-boat pier where we have our instrumentation. Our tubing to the water extends down one of these piers which we have mounted by metal pipe.

Going back to the Bay Marine Lobster, this is a standard float type, as I mentioned before. The float travels up and down in the tubing, and it's a direct link with the water. Now, direct links are good and they are quite simple, and in the end you are looking for simplicity when you install these gauges. This particular gauge is in a concrete sump which was from a preexisting steam generating plant, and it provided an excellent area to put this gauge. It dampens the wave action and tidal effects and we just lucked out when we found this site.

This is your Fisher Porter recorder with the punch tape. We have this one set to punch every 15 minutes, but you can have them record stages every five minutes up to every 60 minutes. These have been the mainstay in the Geological Survey for the past 15 years. So it has stood the test of time. These

run on a 12 volt rechargeable battery which lasts anywhere from four to six months, and it's been working quite well.

Here's your manometer setup. You've got your pressure sensing unit, and it's powered by nitrogen gas for the pressure end. The electrical end is powered by another 12 volt battery. These batteries are rechargeable, and we have them hooked up to wall socket rechargers when we can find wall socket power. This one has a series of gears by which you can drive other recorders. The unit is actually only a sensor so it cannot record, so you must hook it -- in this case we have it hooked to a Fisher Porter digital recorder and a Stevens graphic recorder which draws a graphic trace of the whole tide range.

Here you have a closeup of the chain drive assemblies. If you have a need you can hook up several other recorders providing you have enough space. In this case there was enough space for the recorders and me. It's tight but it does work.

Here you have an example of a tide trace. This graphic is capable of measuring on any number of scales. We have this set on a 1 to 12 ratio so that each dark line equals one foot and the smaller lines equal 1/10th of a foot. The unit however is capable to measuring accurately within 1/100th of a foot. So if you're looking for very small tide changes, this unit could handle it.

Here we have an example of the Simpsons Pier, Roughans Point tide gauge. We have the steel pipe attached to this piling, and with adequate care and hopefully no boats will slam into it, it should remain there until we take it out. As long as the level doesn't change or the pipe is not moved, then the tide data will be good.

In the case of the Atlantic Lobster gauge house, we weren't as lucky to have a good firm fixture. The banks were loose rock and we had to do a little improvising. In this case the primary objective is to keep your tubing from moving. Fortunately in tidal rivers you don't have extreme velocities the way you do in inland rivers, and in this area the storm surges which they hope to measure would be minimal. So we were fortunate that there was plenty of loose rock. We took our tubing, piled plenty of rock on it, and then we ran our set of levels at the beginning of the gauge operation. We also ran levels at the end just to make sure that the tubing hasn't moved. In this case it didn't move and it was in for over two and a half months.

Of course you not only have to tie down your tubing end, you also have to tie down your gauge house as well. Here the spring high tide of this past April was just about to this level, which means that with a storm surge you could be up around the base of the gauge.

Most of our manometer stations are bolted down to concrete decking. In this case the concrete already existed so that was easy. Otherwise we would have to pour concrete. It's good to have a stable gauge house so that it's not flooded or blown away, but you can change the gauge house elevation and not affect the record accuracy or the instrumentation. The important thing to remember is not to move your water end of tubing, because if you move the tubing up, then it's like the water being shallower, you're sensing less water. If the tubing sinks then

it's as if the water becomes deeper.

In the case of the Bay Marine Lobster gauge, there happened to be a nice 600 pounds steel beam waiting for us to attach our gauge house, so security was no problem. Also it was in an industrial park and it had plenty of fencing and people around so vandalism would be at a minimum.

The important maintenance needs of these gauges are really only two. One, you must keep your gas levels maintained. Fortunately these tide gauges are quite stingy as far as their gas usage. One tank, which holds approximately 2000 PSI of nitrogen, can last anywhere from six to eight months. So for remote areas if you can't get back there, you're pretty much guaranteed that you will have gas. If you can manage returning every three or four months, you'll be in good shape.

This unit right here is actually the visual key that let's you know that gas is moving through the system. You'll have bubbles coming through the silicon oil which enables you to visually see that gas is moving.

I'd like to close by saying that we have been recording stream flows for over a hundred years with the U.S. Geological Survey, and this is a new challenge for us to be in the tide gauging end of things. As Mr. Butler said, the Roughans Point area is still under study, and these studies will continue. Certainly the tide gauging will continue through next June, and hopefully the COE will have enough correlating data to help them with their flood predictions.

If there are any questions about the instrumentation itself, I do have a couple of handouts and you might see me afterwards. Thank you.

IMPACTS OF EROSION ON ARCHAEOLOGICAL SITES

DR. SANGER: My name is David Sanger. I'm an archaeologist at the University of Maine, Orono. My co-author, Doug Kellogg, is a Ph.D. candidate at the university. I'll go first and then Doug will show you some details.

Now, most of you know archaeologists deal in things like arrowheads and potsherds, but tonight I'm going to talk about our concerns with the possible increased erosion that could occur if sea levels increase in the Gulf of Maine.

The archaeological sites in the Gulf of Maine constitute our data base for the analysis of prehistoric people's adaptation to the area. So, when I heard that there was a conference that was going to include a considerable component of the possible effects of sea level rise, I got quite interested. Archaeology, of course, or the archaeological sites, are strictly a nonrenewable resource. So that it's not much consolation to us to be told, for instance, that sediments may be reworked and redeposited because once an archaeological site is reworked, the redeposition is of no use to anyone at all.

Along the coast of Maine alone we know of at least 1700 archaeological sites that range in age from about 5000 years ago to the early colonial period. This number is probably considerably less than the actual number of sites that are out there. We don't know the total number because the nature of the surveys to this date has not been good enough, nor have we covered

the entire coastline.

To give you an example, in 1979 we began a program in the Boothbay Harbor region. When we started our survey in that 15 minute quadrangle, we knew of 70 archaeological sites. Three year later we had documented over 200 archaeological sites, and we have reason to believe that similar kinds of in-depth surveys will produce similar disparities between the records as they exist now and what is really out there.

The sites older than 5000 years have apparently been eroded away with rising sea levels. And in fact 5000-year old sites are rather rare. We deal mostly with sites in the vicinity of 2500 to 3000 years ago to the early colonial period.

We're concerned because as archaeologists this represents the only way of finding out about the several thousands of years of occupation of prehistoric peoples in the Gulf of Maine.

There is another area of concern, and that is the fact that archaeological sites are protected by federal legislation when they are damaged by acts that are products of our own civilization (developments). The legislation requires that before work permits are issued, archaeological sites must be sought in the area; that is, a survey be conducted. The sites then have to be tested to a certain extent in order that each site may be evaluated in what is called "a test of significance." A significant site is eligible to be placed on the National Register of Historic Places. A State Historic Preservation Officer in each state comments on the recommendations of the archaeologist, and in the case of the Gulf of Maine, we presume the Corps of Engineers would then be given this data and act accordingly.

In addition to those sites which are deemed to be of significance and therefore protected under law, archaeologists would be providing a mitigation plan which could involve either protection of the sites through some kind of a seawall, or excavation of portions of the sites. All of this takes a lot of time, and I could not even begin to estimate without a lot of work how much time this would take, or what it would cost in terms of man years and dollars.

The results of our surveys in the Gulf of Maine to date have been rather disturbing in terms of the potential impacts of any increased sea levels. Archaeological sites are eroding all through the Gulf of Maine. Our work in the central Maine coast area indicates that archaeological sites tend to erode faster than areas on which archaeological sites are not located. This is because many of the sites are located on low areas, of low ground slope, on pockets of unconsolidated sediments between bedrock. So even though an area may be characterized as having a lot of bedrock outcropping, there will be areas of unconsolidated sediments which are eroding rather rapidly. I will leave these details for Doug.

I'll show a couple of slides now, depicting coastal erosion and archaeological sites. The white that you see is nearly all clam shells, soft shell clams, and great chunks of the site breaking away. This happens to be the Tafts Point site, one of the famous sites in the history of Maine archaeology located in Frenchman Bay.

Every once in a while we come across a site where

someone has attempted to protect the land. Here we see a very primitive sort of seawall that is now several meters in front of an eroding site. I don't believe anyone was trying to protect the site at this point, but simply trying to hold back erosion. There are several meters behind the small row of rocks and the base of the site. The white that you see in the foreground is "shell hash." It is the crushed up clam shell that's being eroded out of the site.

We also have some sites on the coast of Maine which are non-shell sites. This happens to be the Nahanada site, an early 17th century contact period site in the Pemaquid Point area. This site is on the National Register and was excavated because of the fact that it is eroding very rapidly.

In Duck Harbor on Isle au Haut, we have a rather protected area in terms of storm wave activity. Here you see examples of erosion where trees once grew -- see the tree trunk here, and extending right back to where land is now. A similar case over here. Here are some roots sticking out. The land has eroded back this far since the tree started growing. An example of an archaeological site, non-shell site in this case, where erosion is very substantial.

In Acadia National Park we have another National Register site known as the Fernald Point site (Sanger 1980). The Park Service asked us to do some excavation here and then come up with a plan to try to protect the site for the future. In this case someone in the past had constructed a small barrier here. This didn't prevent the erosion you can see going on in this 1976 slide. The erosion showed up shells which encouraged amateurs to go in and do further digging (illegal, of course).

After excavating around the front of the site to recover as much information as possible, we recommended that the Park Service grade the edge back and then cover it with riprap. This picture was taken a day or two after a major storm in the spring of 1978, and you can see the warf remains thrown up on the site. The erosion has steepened the face here, but it seemed to survive the storm. This spring (1985) I looked at it again, and it is still holding up very well. In fact, the average person passing by would not even guess it is an archaeological site.

Other techniques have been tried in the northeast. In Passamaquoddy Bay in New Brunswick, the gabbion technique has been used. I've been keeping an eye on that for several years, and is seems to be working quite well. Then just very recently, the Corps of Engineers put a large seawall in front of the very important Pentagoet site in Castine. So we have these sorts of options for protecting sites.

I'd now like to turn things over to Doug Kellogg who will talk to you about his research in the Boothbay Harbor region, and give you some of the details on what allows us to say that archaeological sites are eroding more rapidly than nonarchaeological sites.

MR. KELLOGG: Several years ago as part of my master's thesis (Kellogg 1982), I did a study of the archaeological sites in the Booth Boothbay region of the Maine coast, which is shown here. There are 190 archaeological sites which I included in my study. In order to compare the types of environments which were selected for occupation prehistorically to

what's available naturally, I generated a random sample of equal size, 190 random locations, and looked at the shore characteristics and the apparent erosion at those 380 locations, and compared the two samples.

What I'm going to do now is show you some pictures of the typical shore types, give you an idea of the erosion classification that I used, and then show you the comparative results.

This is a profile of the typical sand beach which makes up about 1 percent of the shoreline area. This is half of that one percent in the Boothbay region, Pemaquid Beach.

One of the other shoreline types is also a beach type shore, but this is an unconsolidated sediment of almost any character from boulder to mud backed by an erosional scarp of unconsolidated sediments. These go through a range of erosion (Table 1 - See Appendix). In my classification, I classified a sand beach as being totally eroded in terms of archaeological finds. Any prehistoric camp site on a sand beach would have been continually reworked and had lost any usable context.

The next class was a severe class. This is a beach with a scarp type shore with boulders, sands, or mixed sediments backed by a steep erosional scarp with open sediments, and trees falling down. There is obviously rapid erosion taking place here.

This type of erosion, is occurring on the same type of beach with scarp shore, however, tree growth is distorted. There are patches of open sediment, but some of the shore is covered, and I classified this as a medium type erosion. A little bit slower erosion than the previous example.

This is another beach with scarp type shore with a vegetated scarp, trees growing all along the scarp and just a little bit of distortion, a few trees leaning over but mostly no open scarping. So I classified that as a minor erosion.

The predominant shore type is a rocky type shore with a ramp of bare rock between the mean high water and the unconsolidated vegetation zone. This shoreline type makes up about 50 percent of the study area (Figure 2 - See Appendix). The beach with the previous shoreline type, the beach with scarp was 26 percent of the area.

This is an example of a rocky shore, mean high water comes to about here. Here's the vegetation zone and in this case I classified this as minor active erosion. Water seldom reaches up to this level to have an impact on the shore on the unconsolidated sediments or any archaeological sites that might be on this type of shore.

A rock cliff shore has a vertical section, it's basically a vertical rocky shore, and this is another variation on the rock shore. There's an example of a cliff shore. Mean high water reaches to here. There's virtually no erosion of unconsolidated sediments here, or rarely is there any. Cliff shores make up about 10 percent of the shorelines.

The last type of shore is a marsh shore with a fringe or an extensive development of salt marsh up against the shore. In most cases this type of shore was classified as minimal or no erosion because the salt marsh is encroaching over the shore, these sediments aren't being eroded away. Erosion is taking place maybe on the front of the marsh but it's not

impacting this area of the shore. The marsh shores make up about 20 percent of the Boothbay area.

The point is that the erosion is most severe where unconsolidated sediments are exposed at low elevations to marine processes. This happens where there are bedrock gaps in which glacial settlements have accumulated. Water has moved up into those gaps and is continuing to erode (Figures 1 & 2 - See Appendix).

What we find is that sites fall so that we have a high percentage of sites in these severe and medium erosion classes. 67 percent of the sites suffer medium or worse erosion, while only about 13 percent of the random locations suffer medium or worse erosion (Figure 3- See Appendix). This is correlated with the types of shores that they fall at (Figures 1 & 2 - See Appendix).

About two thirds of the sites occur at beach type shores while only about 26 percent of the random locations occur on beach type shores. So that's the major difference.

A similar study (Kellogg 1984) was carried out for 213 archaeological sites in the Muscongus Bay region, next door, with similar results. Most of the sites are suffering medium and severe erosion with less for random locations (Figure 4 - See Appendix).

The locations chosen by prehistoric peoples for their village and camp sites are the types of locations that are eroding most rapidly. A 15 centimeter increase in tidal level may not have much on an impact on a place like Pemaquid Point, but back in the inner coast where archaeological sites are, the mean high water comes almost to the base of the scarp now. 15 centimeters more would bring water close to or right onto those scarps, and it is likely to increase the active erosion that is taking place now.

The 1700 sites we know of are subject to rapid erosion. Any rise in sea level further threatens this nonrenewable resource. The significance of these sites has been established by legislation. The National Historic Preservation Act has said that these sites deserve consideration. Tidal amplification in the Gulf of Maine poses a potential catastrophe for us. But this may be alleviated if we have enough time to do something about it. We're therefore grateful for the opportunity to be here and participate in this conference and present our concerns. Thank you very much. Are there any questions?

MR. GATTO: I have a comment. This summer the Corps held a cultural resources preservation workshop to see if they could discuss some of the different techniques used by the various Corps offices throughout the country to preserve archaeological sites until they had time to get to those sites and classify them however archaeologists do that. If you were interested in getting some information on what ideas were proposed at that workshop, you might get ahold of Dr. Roger Saucier at the Waterways Experiment Station. He was the chairman of that workshop. He might be helpful in passing some information on.

MR. KELLOGG: Any other questions?

(No response.)

MODELING TIDAL ECOSYSTEMS WITH PARTICULAR REFERENCE TO ALTERED HYDROLOGY

MS. SPILLER: I'm Judy Spiller. Along with Charles Vorosmarty, I will be presenting a talk on a strategy for studying tidally induced changes in estuarine ecosystems. We are from the Complex Systems Research Center of the University of New Hampshire, and the material presented here represents a larger project involving other researchers from UNH.

In considering the possible effects of the proposed tidal power project, numerous possible consequences have been suggested. Largely these have been speculative, although this conference represents a movement toward a more rigorous approach to the issue.

The problem arises because the predicted tidal change is really an intensification of existing natural forces. Unfortunately, the natural variability of these forces, including the degree to which they may block or intensify each other is poorly understood. When information and understanding are limited, changes in these forces are very difficult to predict and causality difficult to assign. It is not yet known how to measure incremental changes that may result from an altered tidal regime and then to identify them as a new perturbation of the system.

We think that ecosystem modeling, linking hydrology with biological processes, offers the opportunity to approach this problem in two related ways. One is to develop some predictive capacity by using modeling in a simulation sense; the other is to develop a baseline against which change may be evaluated, if a project like the tidal power project is ever built.

MR. VOROSMARTY: As an example of this approach, we will describe a strategy developed for studying the Parker River ecosystem in coastal Massachusetts. The Parker River estuary is very typical of marshes on the Massachusetts coastal plain (Figure 1 - See Appendix). The important questions that we believe can be addressed will be how nutrient cycling, hydrodynamics, biology and chemistry are all linked in a single ecosystem and how those linkages express themselves in the water quality that we can measure in the field. We believe this strategy can be extended to help predict the effects of the Fundy project.

Figure 2 (See Appendix) summarizes our approach. There are two fundamental components: a water quality monitoring component, including field and laboratory experimentation, and a modeling component. Over short intervals of time, one to two tidal cycles, and including both spring and neap tides, we have studied water quality at different points along this system and at its boundaries.

Simulations with this monitoring program, we've performed subsystem process experiments isolating different subcomponents of marsh and tidal inlets, (i.e. microcosm experiments) looking at the kinetics of exchange between the particular substrate we've isolated and the water column above it. Together with information on the bathymetry of the study site, the results of the process experimentation and boundary flux information are run through a digital simulation of the study site. The backbone of this model is a one-and-a-half dimensional tide propagation model developed at MIT in the 1970's.

Both the modeling and the monitoring phases of the research produce either timeseries plots or input/output budgets that summarize nutrient flux through the system. When there is a difference between these two products of our research effort, we recalibrate either our model or our field program in order to reduce that difference.

This self-checking process occurs at three different scales of spatial resolution, starting with the simplest or the microcosm level of analysis, and progressing to a large scale study of the entire ecosystem (Figure 3 - See Appendix). Starting at the microcosm level, we obtain characteristic types of sediment and plant communities, and measure the biogeochemical transfers operating in these small enclosures, which contain a relatively homogeneous type of substrate. We also perform process experiments to elucidate the hydrodynamic controls.

Once this is complete, we progress to a larger, mesocosm scale of resolution. Mesocosms are small salt marshes, perhaps five or fewer hectares in extent, well bounded, and drained by a single tidal inlet. If we choose our study sites properly, we can physically alter the hydrology of those parcels of landscape. We can then observe in the field the impact of altered tidal hydrology on nutrient cycling. Again, we concurrently will be modeling and performing field experimentation.

When we are ready to consider the full Parker River ecosystem, obviously we will not be able to alter the hydrology of the study area. But by compiling our detailed field program to a sufficiently rigorous model of the entire ecosystem, we can proceed to alter the tidal hydrology, this time within the model ecosystem. Thus we can gain insight into what the effect of altered hydrology might be on a large typical marsh system in coastal Massachusetts.

Our first look at the Parker River's nutrient chemistry came in October of 1983. We contrasted spring and neap tides, which are times of very different hydrodynamic forcing functions moving water into and out of the study site. Figure 4 (See Appendix) shows the resulting salinity/nutrient plot for ammonium in a neap tide setting.

The very large peak occurring at about 24 to 28 parts per thousand salinity indicates that there is a dramatic source of ammonium in the study site, at least in a neap tide situation. Figure 5 (See Appendix) shows on a similar scale the plot for a spring tide situation. Again there is a pulse, although it is far smaller than the pulse occurring during neap tide.

It could be argued that these results are a function of dilution; if true, we would see a similar neap-spring divergence for other nutrients as well. Figures 6 and 7 (See Appendix), showing salinity-nutrient plots for phosphate, disclose no such divergence. So either there is a net sink for ammonium in the study site when the marshes are extensively flooded, or there is a selective source of phosphorus. We do not yet know which, but clearly there is a quantitative difference between these two hydrodynamic settings.

Further evidence that there is a link between hydrodynamics and nutrient cycling were found in an earlier study

of the North River ecosystem, also located in coastal Massachusetts. There we examined hydrodynamics and nutrient cycling in a tidal fresh water marsh from 1979 through 1982. Table I (See Appendix) contrasts samples from a single tidal cycle in July 1980, which was virtually normal by North River standards (the marshes were flooded for approximately three hours during the tidal cycle and well-drained at other times), with another set taken in June 1982.

At the later date severe flooding in the upriver basin choked the marshes with fresh water for virtually the entire tidal cycle. By using information collected during our field program and coupling that to flows predicted by the model, we constructed input/output budgets over a full tidal cycle, tabulating the amounts of nitrogen coming into and exiting the system, and by difference what the inferred exchange might be.

In the earlier, well-drained setting, about one kilogram of ammonium nitrogen was released from the ecosystem, passed into the water column and later transported across the seaward boundary. In contrast in June 1982, we see a much greater quantity of ammonium nitrogen moving into the water column.

One possible explanation for this effect is that extensive flooding of the system waterlogs the substrates, inducing anaerobic metabolism. In this case a different type of chemistry is invoked. Evidence for this shows up in microcosm experiments performed on North River sediment collected at about the same time (Figure 8- See Appendix). Under aerobic conditions the leaf litter effectively strips the water column of nitrogen. However, if the systems are anaerobic, the litter becomes a source for nitrogen which passes into the water column. So there is a switching mechanism at the microcosm level, but visible at the ecosystem level as evidenced by the input/output budget described above.

Thus, ecosystems send signals which can be detected in both our field monitoring programs and in small experimental vessels. Through integrative multidisciplinary research we hope to build some predictive capability, to see just how far we can push these systems by altering the hydrology before they deteriorate significantly.

Dying saltmarshes are a serious ongoing problem. We have begun studies on two small marshes in the town of Northhampton, New Hampshire. Each has a constriction which impedes flow of tidal water into and out of the marsh. Our first marsh maintains high productivity and appears to be in a fairly healthy state, but a species inventory shows that there has been a progressive incursion of fresh water species moving towards the south of the system. In this case altered hydrology reduces flushing at the seaward end of the system, permitting a more freshwater type of chemistry to become established.

The other marsh has not fared quite as well. The reduction in the amount of tidal flushing has produced highly significant impacts on this marsh. Reduced fresh ground water sources prevent the replacement of salt with fresh water marsh, and what is left of the salt marsh basically is dying off. There are numerous pan areas that are beginning to go anoxic, and there are no healthy marsh macrophytes in these areas at all.

So it is not outside the realm of possibility that

the Fundy tidal power project could culminate in some very significant ecosystem-level changes in coastal marshes. The impacts of the power station may not necessarily take the same form as those operating in the Northhampton marshes. But there are fundamental linkages between the health of these biologically active systems and the hydrodynamics to which they are adapted. Our task now is to carefully identify the linkage and use our understanding to predict environmental impacts.

GROUND WATER IMPACTS OF RISING SEA LEVEL AND DEVELOPMENT

MR. TOLMAN: I'd like to thank you all for hanging in there. I'm Andy Tolman. I will not turn the lights off and show you slides. I'm not going to try to keep up with the graphics that have been here, and I will also be, I hope, very brief and perhaps to the point. And that's partly because we're going to be talking about groundwater and impacts of sea level change on groundwater, and we know relatively very little about that. So therefore, I shouldn't keep you too long telling you what we don't know.

But let me lay out kind of a scenario for you, and I guess we've been talking hydrodynamics, a few hydrodynamics facts.

When you have a coastal situation where you have a saltwater and fresh water interface, where you have fresh water flowing out into saltwater, you get a fairly easily understood physical relationship between them. That's that for every foot you pile fresh water up above mean sea level, you have a depression of the saltwater about 40 feet below mean sea level. As you move either of those up and down you get an alteration of that, obviously. If you move sea level up a little, then the saltwater interface moves up a little.

The bigger the incursion of saltwater, the bigger the change in either saltwater or fresh water, the larger mixing zone you get. That's one thing to think about. The other thing that happens is that as you drill wells that are near that saltwater/fresh water interface as it moves up and down, you have a larger chance of getting brackish wells.

If you can think back to some of the slides we saw this afternoon, you'll remember that the middle part of the coast of Maine is fairly deeply indented. It's a series of peninsulas that are very attractive, and we're kind of on the western edge of that area right now. Those peninsulas have traditionally been inhabited in large part by summer homes. They've been developed for years, but most of the people have gone home in the winter. They've had summer water systems which are run along the bare bedrock and fed by local ponds or lakes. However, more and more people have decided that those are nice places to live year round or nearly year round, and they are moving in there.

The summer water systems are shut off September sometime. So the people drill bedrock wells. They have essentially no surficial cover so they can't do anything else, and as more and more of them stay there year round, more of more of them are starting to see saltwater intrusion problems into their wells even given the current situation.

We don't have good statistics. The last survey we did of the coastal communities was in 1978. At that point about

25 percent of the coastal communities had some saltwater intrusion problems. When you consider that the south coast of Maine, essentially up to Portland, is served by public water almost completely and therefore has no saltwater intrusion problems, then you realize that the rest of the coast, the other two thirds, probably are looking at perhaps 30 or 35 percent of the communities with some problems. And most of those are concentrated in the mid-coast.

Now, that's in part because those coastal communities are located on areas that are very poor aquifers. They are highly metamorphosed bedrock which is sparingly fractured and all the water movement as far as wells are concerned takes place in those fractures. The way those fractures are linked up and the way they trend controls how much water gets to your well and of what quality that water is. If you happen to hit a set of fractures that trends out to sea, the chances of your getting a saltwater intruded well are much greater than Mr. Gyben and Herzberg would suggest, because your recharge area would be under the ocean somewhere rather than under the peninsula where you'd like it to be. So there are a number of imponderables that govern whether an individual will have a saltwater problem. But when you start looking at it on a community scale, you will up the ante a little bit for every foot sea level rises because you will be reducing the prism of fresh water slightly.

If I can run through what's going on here. Primarily we're facing in part a coast that's being depressed for one reason or another, perhaps by the weight of water overlaying the shelf around it. And we're also facing a locally rising sea level. If you add on to that a slight increase in tide amplitude, you're working several factors towards having more saltwater problems. If you add the growth in coastal Maine, and coastal Maine is the part that grows because it is pretty, and the resultant reduction in the available fresh water, then you have a number of small factors that may add up to a fairly severe problem. And everyone will say, well, yes, we can run these people public water, and that is true, but it's one of those costs that you've got to look at. It's a secondary or tertiary cost associated with a number of factors, one of which may be tidal power, and it will be a fairly high cost because you're talking about running public water supplies through areas that are essentially bare bedrock. So as those of you who are engineers know, you start blasting for water lines, it gets really steep.

But, as I said, I don't have a whole lot of facts. I could have shown you some pretty pictures of the indented coast, but basically that's what we know and what we don't know. We would like to know more about exactly how many areas do have saltwater. We are working to find out more about how those fractured bedrock systems work. Our understanding of them is very rudimentary, and what kind of recharge rates we're looking at in those systems. And we've gotten estimates anywhere from four to ten inches a year of recharge. That's a fairly broad range to be working from.

As I said, it's kind of late at night to be telling you what we don't know, but that is what we don't know, and we hope to find some of it out perhaps with your help. Thank you.

RESEARCH AT CERC'S FIELD RESEARCH FACILITY, DUCK, NORTH CAROLINA

I'm just going to talk a little bit about the CERC Field Research Facility: What we are, the kind of work we do, and a couple of the major results we've had in the last year or so.

We are a branch of the Coastal Engineering Research Center which is located at the Waterways Experiment Station in Vicksburg, Mississippi. Our purpose is to conduct coastal research studies of the beaches surf zone and nearshore bottom, particularly during storms, since storm processes are most important in the movement of sand and the effect of waves on the coast. The Facility also serves as a base of operations for other types of studies -- ecological, marsh planting, various types of things which I'll talk about. Finally, it also provides a field site for testing and evaluation of new types of equipment and procedures.

The Duck site which is located on the northern end of the Outer Banks, about ten miles north of the Town of Kitty Hawk, North Carolina, was selected because it is a site which is representative of many other U.S. coasts. For example, although this is a regional conference for the Northeast U.S., we feel that the Duck site offers potential for research studies that would benefit this area as well. John Boothroyd, University of Rhode Island, brings his graduate students down once every couple of years to look at the sands of Duck and talk about the processes, because these processes are universal. We have a location which has a wave climate, a sand size, and a meteorological climate which are relatively typical of many coastal sites in the United States.

We're minimally interfered with by man's effects. There are no structures near the research pier to affect the nearshore processes, although the resort nature of the area is encroaching somewhat on the site. We can also conduct a wide range of studies because of the physical limits of the sites.

We own 176 acres extending 3300 feet alongshore and from the ocean to the sound. The facility consists of the laboratory building, which houses the office space and computer facilities and so on, and the 1840 foot long research pier which extends out to a water depth of about 20 feet at an elevation of about 25 feet mean above sea level.

We also have recently completed construction of this vehicle storage building.

The staff is small but dedicated, consisting primarily of oceanographers and hydraulic engineers as well as technicians and computer operators. Our equipment is unique and is absolutely necessary for conducting our coastal research studies. The coastal research amphibious buggy (CRAB), this 3-wheel vehicle powered by a Volkswagen engine, is capable of carrying three men or three women out to sea to water depths of 30 feet. It is used primarily for near shore surveying. We use a Ziess Elta-2 total station, a state of the art surveying instrument which emits a laser beam that bounces off reflecting prisms located on the CRAB and then back to the instrument.

The horizontal position of the CRAB and the bottom elevation are computed automatically by the instrument to an accuracy of plus or minus 2 centimeters at a range of up to 1.5

miles.

The CRAB is also used for collecting suspended sediments samples, for coring, vibracoring on the barrier island or in the surf zone, which is a rather difficult area to work in for most platforms.

We also operate an amphibious vehicle known as the LARK 5. This is used to support our diving operations. 60 percent of our staff are divers and there is a great deal of diving involved in the work that we do.

The primary research study is the field measurement and analysis program. This consists of two major areas of investigation. The first of these is the collection of long-term data for improved design of coastal projects and improved understanding of the statistical nature of wave and meteorological processes. We collect wave data from a number of gauges. Near shore we have Baylor wave gauges, which are staff gauges located on the pier. We have now two waverider buoys, one in 30 feet of water and one in 55 feet of water for investigating the wave transformation process as waves enter the surf zone and break. We can also operate a radar for wave direction imaging. We will be operating a CODAR system that was mentioned earlier for looking at the spatial distribution of waves and currents in the nearshore zone.

This is a typical wave rider buoy wave gauge after we brought it in. We do have problems with biological fouling and growth. We can write a book on the maintenance procedures required for nearshore instrumentation that are in for the long term.

We also operate an Sxy gauge. This is a directional wave gauge, developed by Scripps Institution of Oceanography, and provides us with some direction wave measuring capability.

Nearshore currents are measured using a Marsh McBirney electromagnetic current meter located in 20 feet of water, approximately six feet above the bed. This provides some very interesting long-term data on the nearshore current circulation data which are not being collected anywhere else.

Tide data collection is supported by the National Ocean Services with two gauges on the pier and one in the sound behind the pier. We're looking at storm surge elevation, the history of extreme water levels, at the mean monthly variability in water levels, at all the types of the water levels that were discussed earlier today, and we're getting some good statistics on the ocean and sound characteristics.

Water temperature and salinity are measured daily at the end of the pier, and we also maintain a full suite of meteorological instruments which are hard wired into the computer. Data is collected from the electronic instruments four times a day during normal conditions and put directly on magnetic tape for subsequent analysis.

During storms (which occur roughly 10 to 15 times a year), the data collection is increased to hourly. The samples are 20 minute records collected at four times a second, although we do occaisionally collect 80 minute records for looking at infragravity wave activity during storms. The facility was fully operational in May of 1980 and most of the data that I'm talking about have been collected since that time. Aerial photographs of

adjacent beaches are taken quarterly, and bathymetric surveys are made monthly.

The surveys that are made with the CRAB are done along approximately 25 profile lines extending from the dune out to a water depths of 30 feet.

Maps like this are developed monthly for the property limits extending approximately 1700 feet either side of the research pier. This is a fairly simple bathymetry shown here. We're looking at the depth contours in meters, and we see that there is a scour hole at the end of pier. This is in July, and that hole is rather small in the survey compared to what it can be during the winter, when storms elongate it, deepen it and cause a tremendous perturbation in the nearshore zone. We are taking steps to make more of our measurements away from the pier.

The other work unit that is involved at the facility is the storm erosion studies work unit. The objective is to look at the effects of storms on the shoreline, and the nearshore bar systems, and to look at waves transformation processes during storms as well.

Whereas the previous study involved long-term data collection, this one concentrates on the short-term processes, which can be significant. Significant wave heights during an average storm at the pier are in the neighborhood of 3 and a half meters at the seaward end of the pier compared to a mean annual wave height of about one meter.

The CRAB is used to conduct pre and post storm surveys, as well as to obtain sediment samples prior to and after storms. We try and get out during the storms to look at the profile response, but it is difficult since the CRAB is limited to wave heights of about two meters.

Shown are some of the results from these profiling efforts. This is the most interesting suite of profiles we have collected at the pier, showing the effects of storms. We're looking at the period of 5 October '81 through 16 November '81. The upper line here is the significant wave height at a water depth of 5.5 meters. Three major events occurred, one early in October, then in late October and finally around the 16th of November, when maximum wave heights of about four meters occurred.

If we look at the profile changes along a profile located approximately 500 meters south of the pier, we see the first storm produced a seaward translation of the nearshore bar of about 40 meters.

During the next storm, we see that the bar migrated offshore again another 54 meters. And finally, with the big storm, a seaward movement of 78 meters occurred. An interesting thing here is that the net volume change was very small, even though on the profile. The erosion here and deposition in these two places was large. This indicates that the transport was almost totally in the crossshore direction, i.e. there was little longshore transport influence on this particular profile.

When we did a volume computation over the total survey area, we found the same result: that the transport into the area is balanced by the transport out, and we are looking at very small net changes.

For your information, this offshore bar stayed out

here for about the next year and a half, very slowly migrating toward shore. This type of data is unique in the world. They have never been collected before, nor are they being collected anywhere else today. As a result, we're getting a very good handle on the processes controlling nearshore sedimentation.

The seaward limit of net sediment change is our next topic. If you take a group of profiles, in this case a year's worth of profiles, at what offshore point do they pinch out to a depth which is the same; that is, where is the seaward limit of profile change. There we see the annual variation in depth at any particular location. On the upper beach we have elevation ranges of about a meter and a half. They increased to almost two and a half meters in the surf zone, and then decreased here at the seaward end of the profile to about 16 centimeters; that is, over a period of a year there was a vertical change of about 16 centimeters. We call that the closure depth because of our surveying inaccuracies and other reasons.

So we have a closure depth of about 5.92 meters for that one-year period. We have compared this to predictions that were made by an analytical technique that the Corps is using to design structures, and we found that the analytical technique predicted a depth of about 6.5 meters based on the annual wave climate. So we can provide good, hard field data for verifying analytical and numerical models.

We're also conducting work for Districts within the local area and elsewhere. We conducted a survey of the bottom changes resulting from the installation of artificial seaweed at Cape Hatteras.

To do that, we constructed a small sled that is used in a manner similar to the CRAB. It consists of a mast to hold the prisms, and the sled is towed by a small boat.

We're conducting surveys in the Kitty Hawk area for the state of North Carolina, looking at spot erosion. There's an area about 5 miles long that is eroding at a rate three times that of the adjacent areas, and we're trying to define the processes that are controlling this process. It's rather interesting. To do that, we're using a sled with a much higher mast. We can get out to a water depth of 30 feet with this particular sled, and we tow it offshore with the LARC and use our Zeiss to determine its position and elevation. It's a more portable system than the CRAB and has worked very well not only in the Kitty Hawk area, but also at Assateague Island, Maryland.

Last weekend we just completed some surveys for the Park Service and the Baltimore District looking at Assateague profiles, again, from 30 feet of water in the ocean, across the island to the bay side. We'll be comparing those to previous surveys to quantify the landward migration of Assateague Island, and to assist in sediment budget calculations.

The facility also provides a location and data for coastal research studies by non-Corps investigators, thus taking advantage of other researcher's capabilities and enhancing the coastal engineering community's ability to do field work. Our policy is to encourage use on a not-to-interfere-basis. We normally provide the pier and routine data free of charge.

Other government agencies that have been involved with the facility over the past four years are listed here. Heavy

users are the Navy and NOAA. We have three Navy radars on-site taking data from time to time.

University users are primarily Mid-Atlantic region, but we do get some from Oregon State, the West Coast, the University of Washington, and other distant locations.

I think our most productive research investigations have been the multiagency cooperative efforts that we've engaged in over the past five years. The first of these, Duck-X, was done in 1979. It was primarily a remote sensing experiment. This was followed in 1980 by the Atlantic Remote Sensing Land Ocean Experiment, ARSLOE. The major objective, again, was remote sensing evaluations, but we also looked at wave transformation processes. 35 different agencies all were involved in that cooperative effort.

In 1981, we conducted a sediment texture experiment looking at changes of sediment on the profile, and in 1982, with the U.S. Geological Survey, Oregon State and the University of Washington, we conducted a nearshore processes experiment looking at the effect of infragravity waves on nearshore bar morphology. We found them to be tremendously important in controlling the response of the nearshore bars to storms.

We also have very good working agreements with the military. They do things for us that nobody else can do.

Finally, we are involved in cooperative efforts of a longer term nature with NOAA. In this case installing some experimental tide wells so that the tide gauging program that NOAA runs can test new equipment procedures.

The site is also heavily used for testing and evaluation of other types of equipment. In this case a hurricane wave and surge measuring device that is deployed prior to hurricanes was dropped from a helicopter and then settled to the bottom, where it is designed to wait for the hurricane's passage and measure waves and water levels.

The site is used twice a year for the Corps' wetlands development workshop and also some dune grass planting work. We conduct a number of seminars and public education activities throughout the year. We publish annually a summary of our data, and every month put out a monthly summary that is distributed to about 80 users. These reports provide a good basis for student projects and perhaps thesis investigations of the long-term statistical nature of the parameters that we measure.

(Whereupon at 10:36 o'clock p.m., the conference was adjourned, to reconvene at 8:00 o'clock a.m. on Thursday, November 1, 1984 at the same place.)

APPENDIX

WEDNESDAY, OCTOBER 31, 1984

7:30 p.m.

EROSION OF BOOTHBAY REGION SHORES

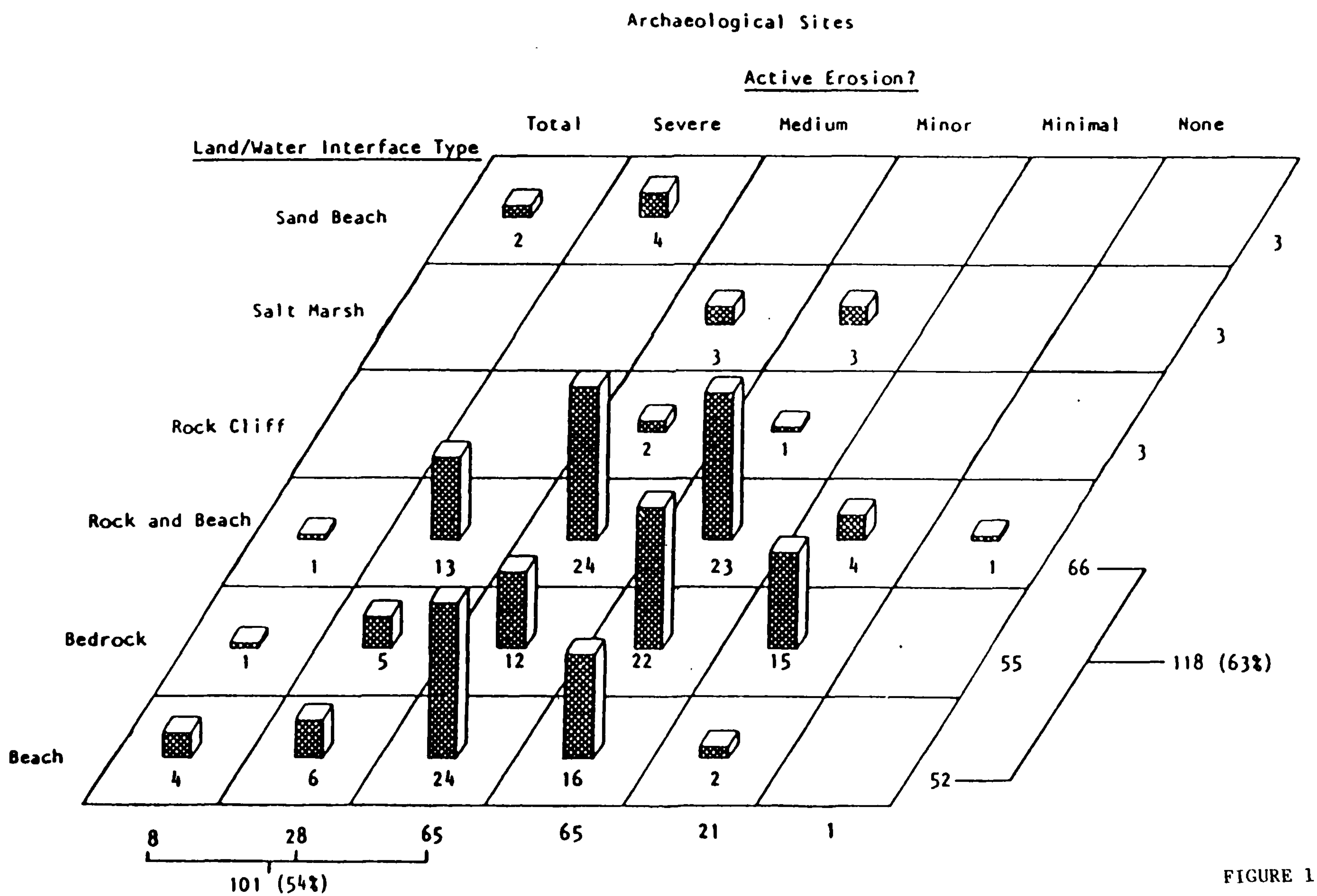


FIGURE 1

EROSION OF BOOTHBAY REGION SHORES

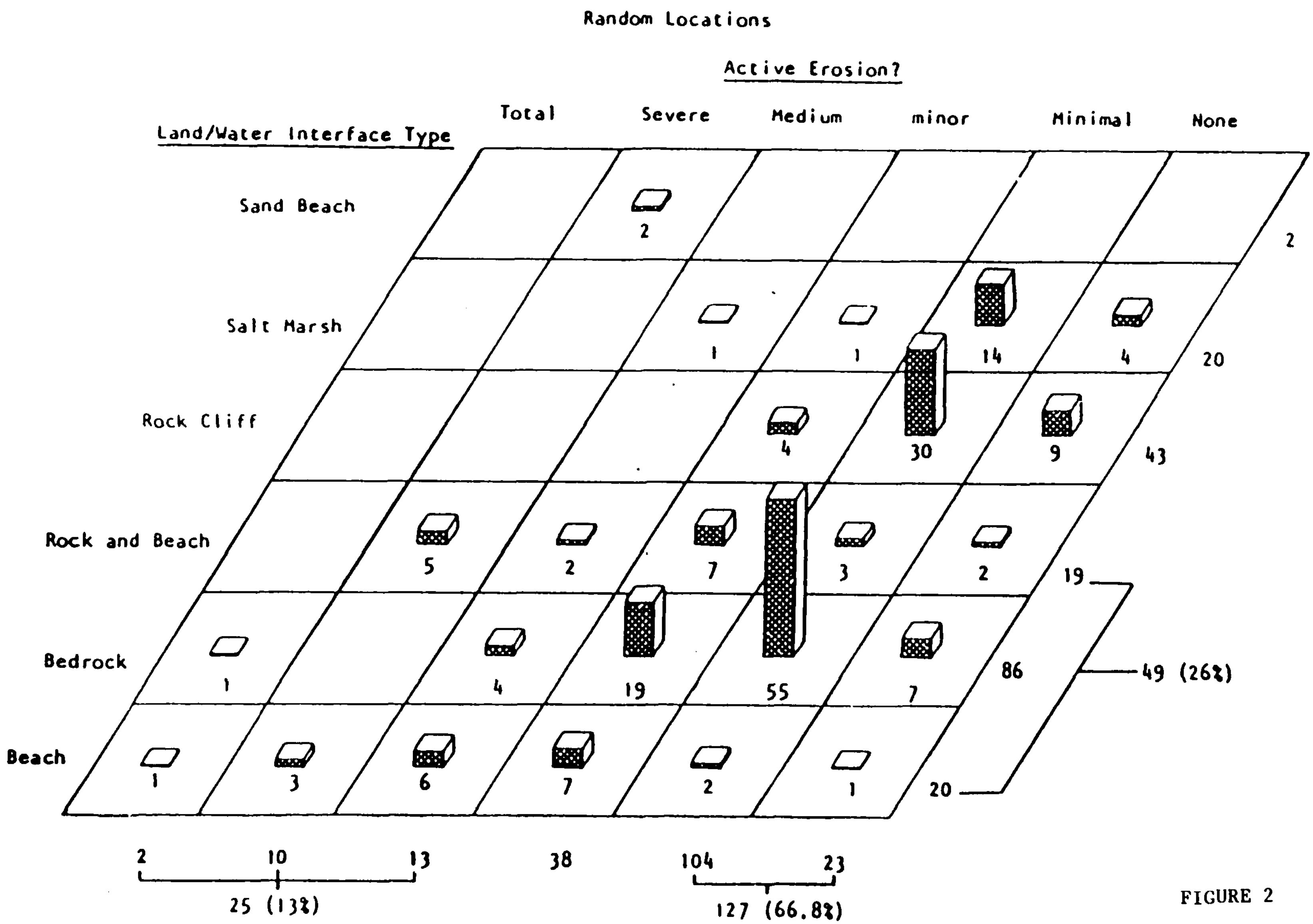
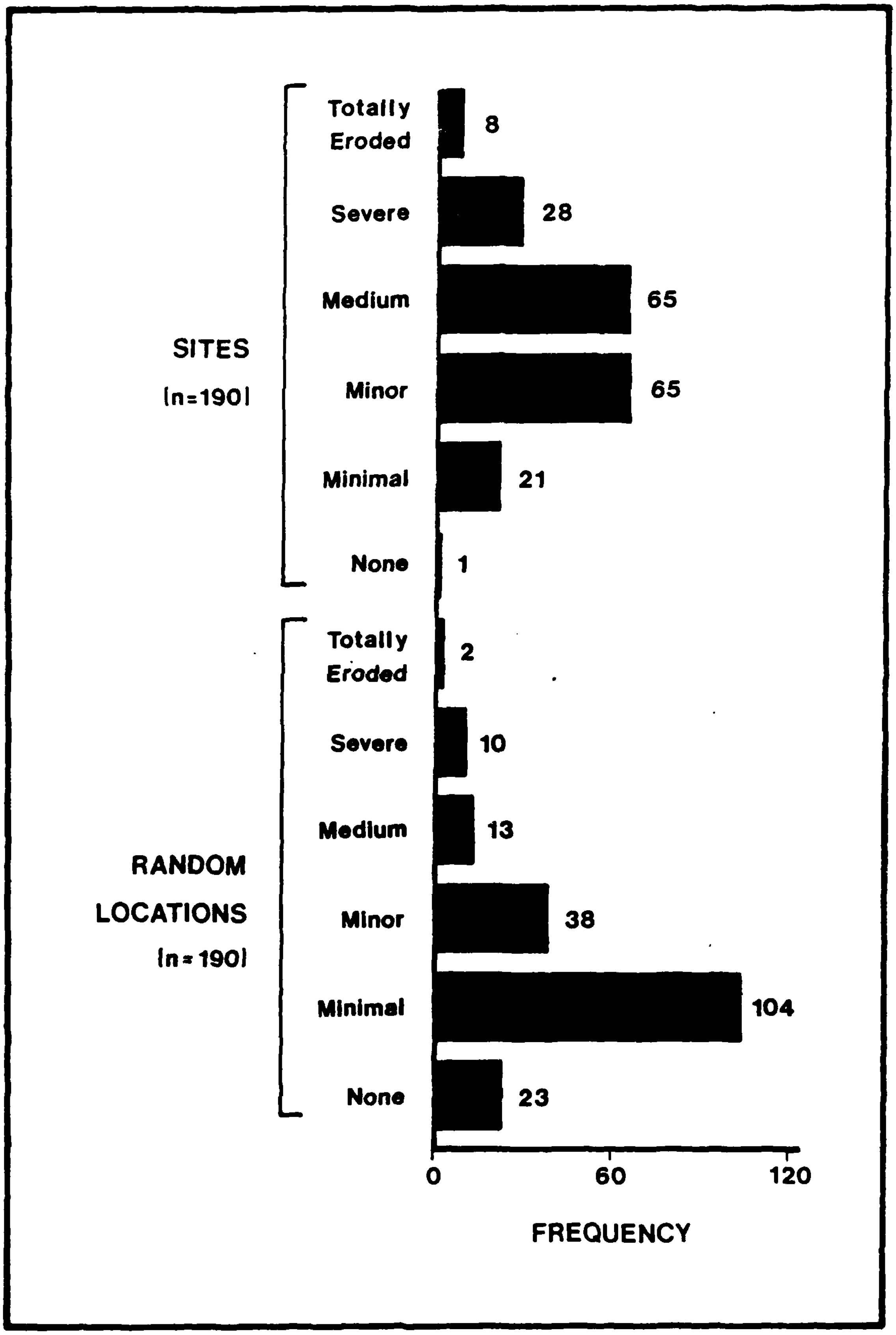
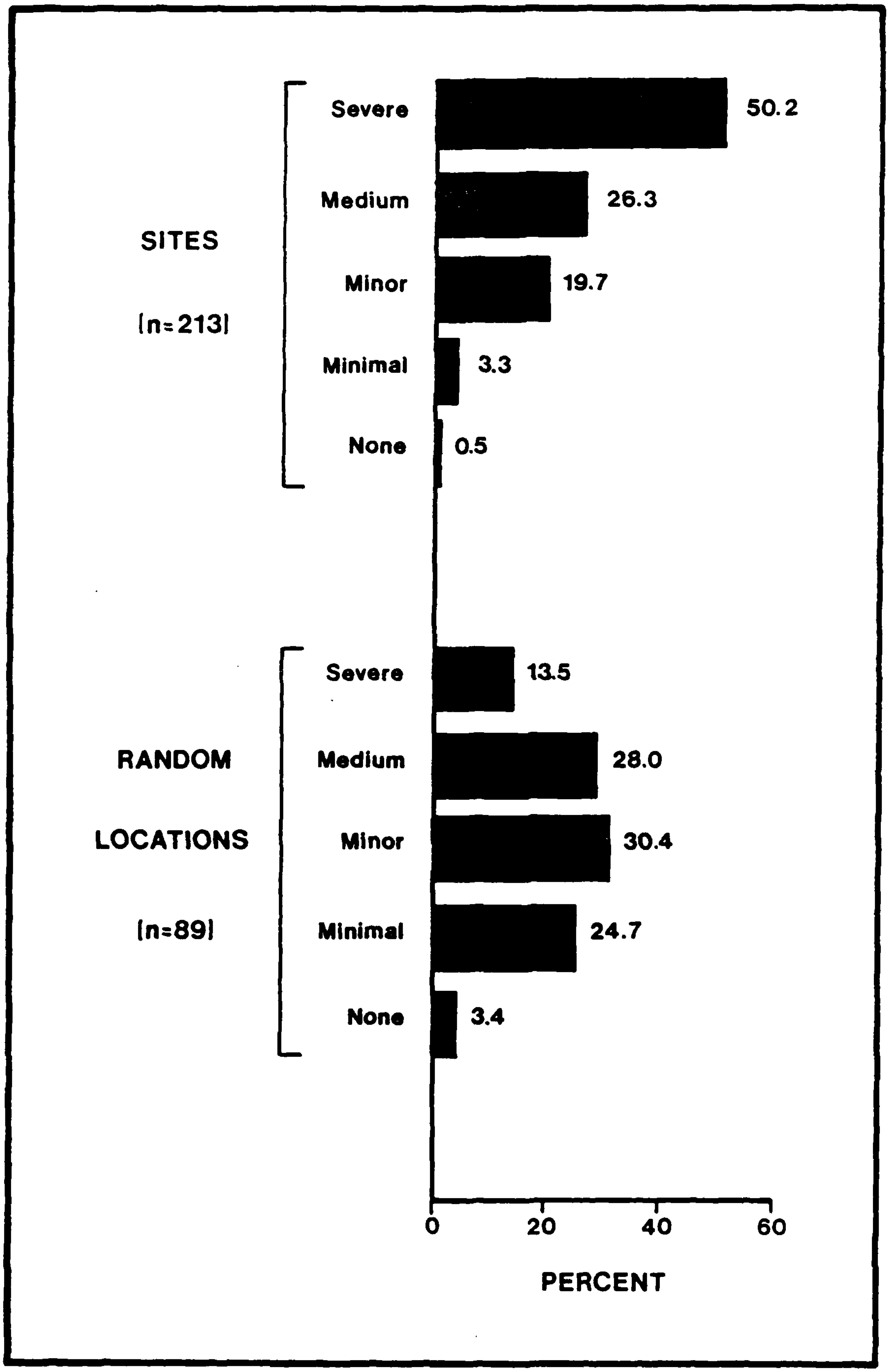


FIGURE 2



BOOTHBAY 15' QUADRANGLE

FIGURE 3



MUSCONGUS BAY / ST. GEORGE RIVER REGION

FIGURE 4

TABLE 1 Definitions for Relative Erosion Classes.

Class:	Definition
Totally Eroded:	Either, high energy sand beaches where yearly cycles of berm construction and erosion insure that archaeological sites have been destroyed, or where historical documents indicate that an archaeological site has eroded.
Severe Erosion:	Extensive, high-angle scarps of unconsolidated sediments. Active slumping of sediments is obvious. Trees have been undermined and fallen and an under cut root zone may be present.
Medium Erosion:	Smaller scale scarps than "severe" class. Only patchy exposures of unvegetated, unconsolidates sediments. Trees leaning or trunk growth distorted, but no toppled trees.
Minor Erosion:	Small scarps with same exposure of roots. No exposures of unvegetated sediments. Trees are not leaning, but trunk growth may be slightly distorted.
Minimal Erosion:	Some exposed roots, but no erosional scarp. Undistorted tree growth.
No (None) Erosion:	High bedrock shores and cliffs, or salt marsh shores where no modification of the pre-existing shore form is now taking place.

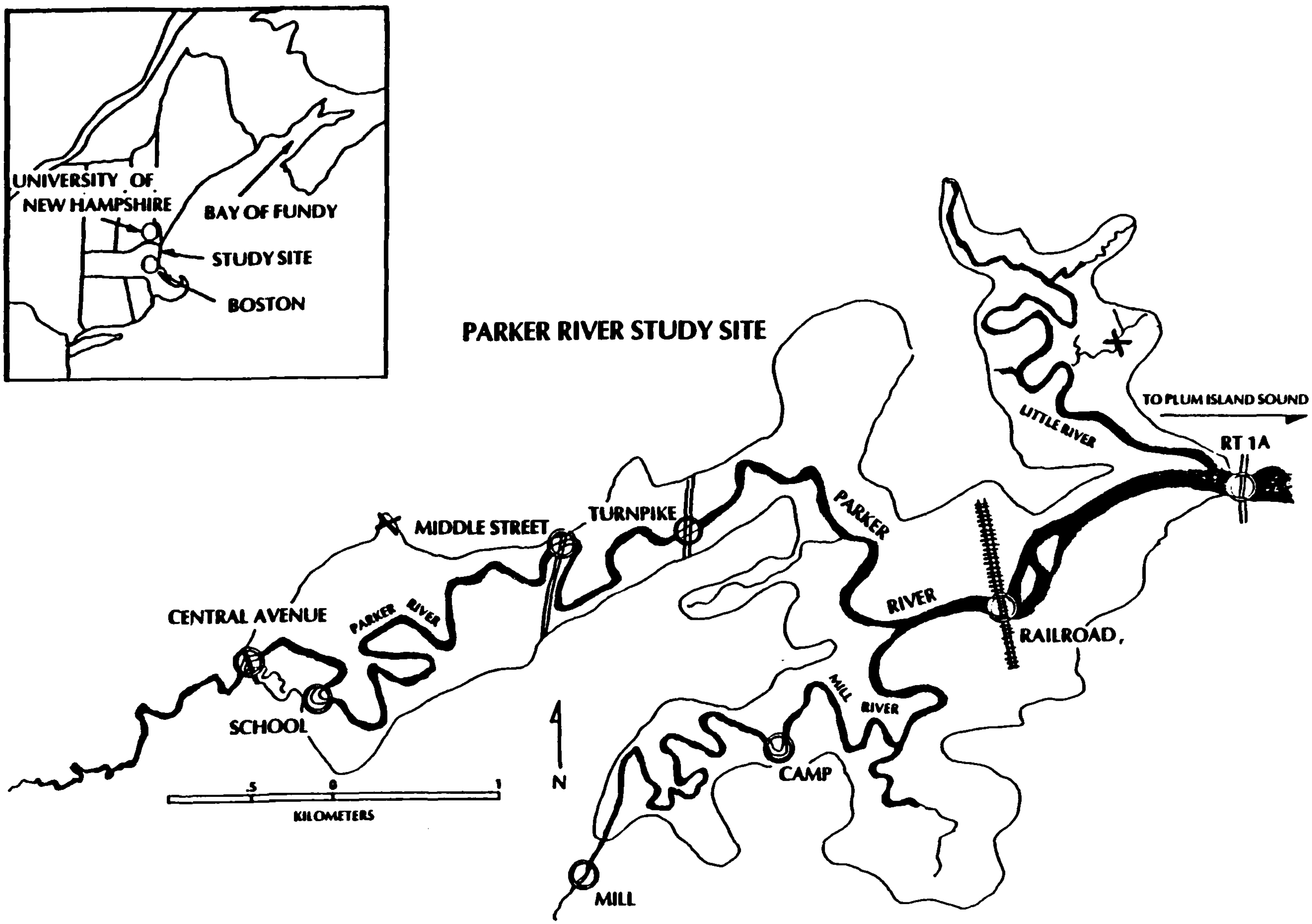

PARKER RIVER STUDY SITE
UNIVERSITY OF NEW HAMPSHIRE
BAY OF FUNDY
STUDY SITE
BOSTON
TO PLUM ISLAND SOUND
RT 1A
LITTLE RIVER
PARKER
RIVER
RAILROAD,
TURNPIKE
MIDDLE STREET
CENTRAL AVENUE
PARKER RIVER
SCHOOL
MILL RIVER
CAMP
MILL
N
.5
0
1
KILOMETERS

Figure 1

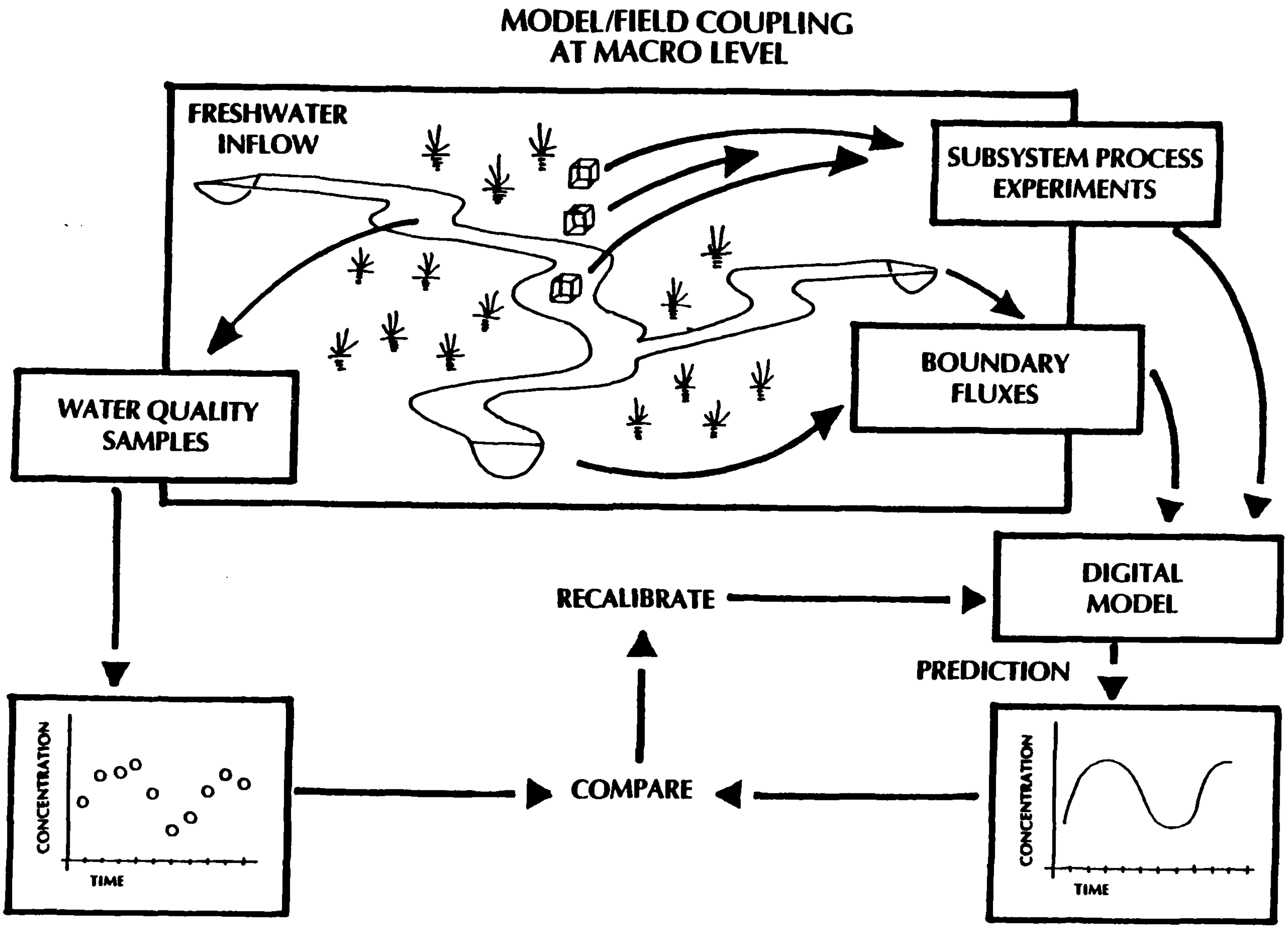

MODEL/FIELD COUPLING
AT MACRO LEVEL
FRESHWATER INFLOW
SUBSYSTEM PROCESS EXPERIMENTS
BOUNDARY FLUXES
WATER QUALITY SAMPLES
DIGITAL MODEL
RECALIBRATE
PREDICTION
COMPARE
CONCENTRATION
TIME
CONCENTRATION
TIME

Figure 2

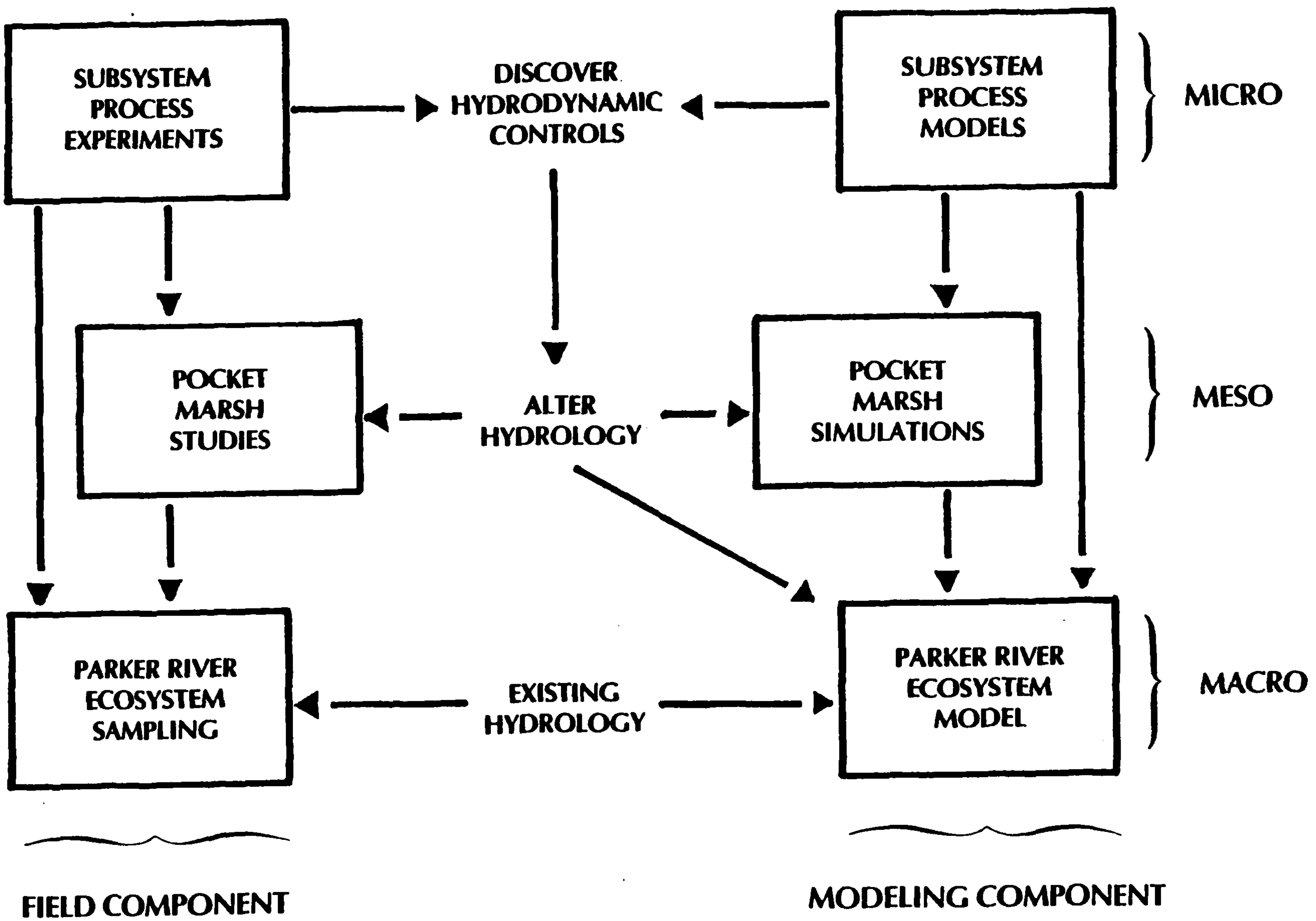
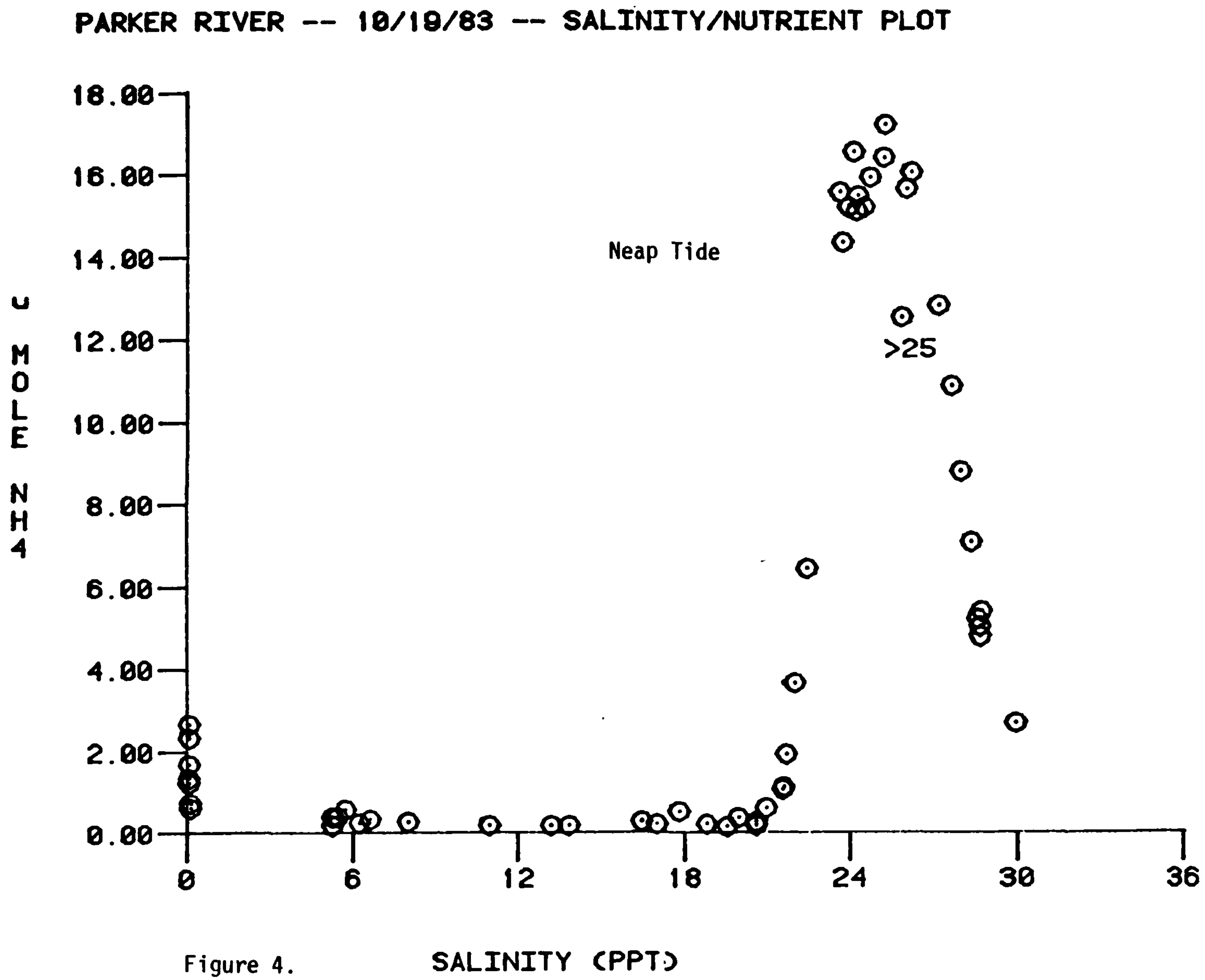

SUBSYSTEM PROCESS EXPERIMENTS
DISCOVER HYDRODYNAMIC CONTROLS
SUBSYSTEM PROCESS MODELS
MICRO
POCKET MARSH STUDIES
ALTER HYDROLOGY
POCKET MARSH SIMULATIONS
MESO
PARKER RIVER ECOSYSTEM SAMPLING
EXISTING HYDROLOGY
PARKER RIVER ECOSYSTEM MODEL
MACRO
FIELD COMPONENT
MODELING COMPONENT

Figure 3



PARKER RIVER -- 10/19/83 -- SALINITY/NUTRIENT PLOT
u MOLE NH4
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Neap Tide
>25
0
6
12
18
24
30
36
SALINITY (PPT)

Figure 4.

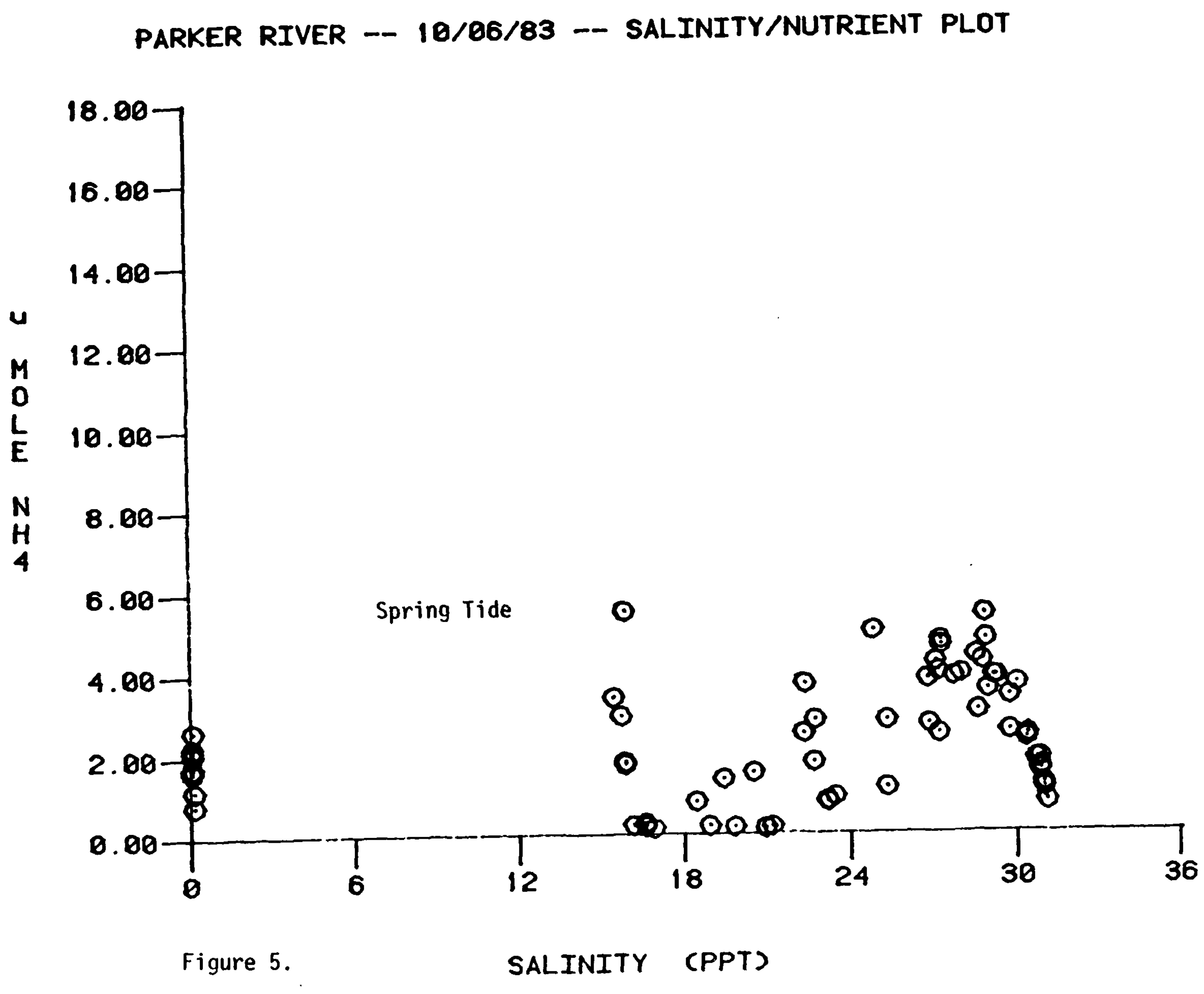

PARKER RIVER -- 10/06/83 -- SALINITY/NUTRIENT PLOT
u MOLE NH4
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Spring Tide
0
6
12
18
24
30
36
SALINITY (PPT)

Figure 5.

PARKER RIVER -- 10/19/83 -- SALINITY/NUTRIENT PLOT

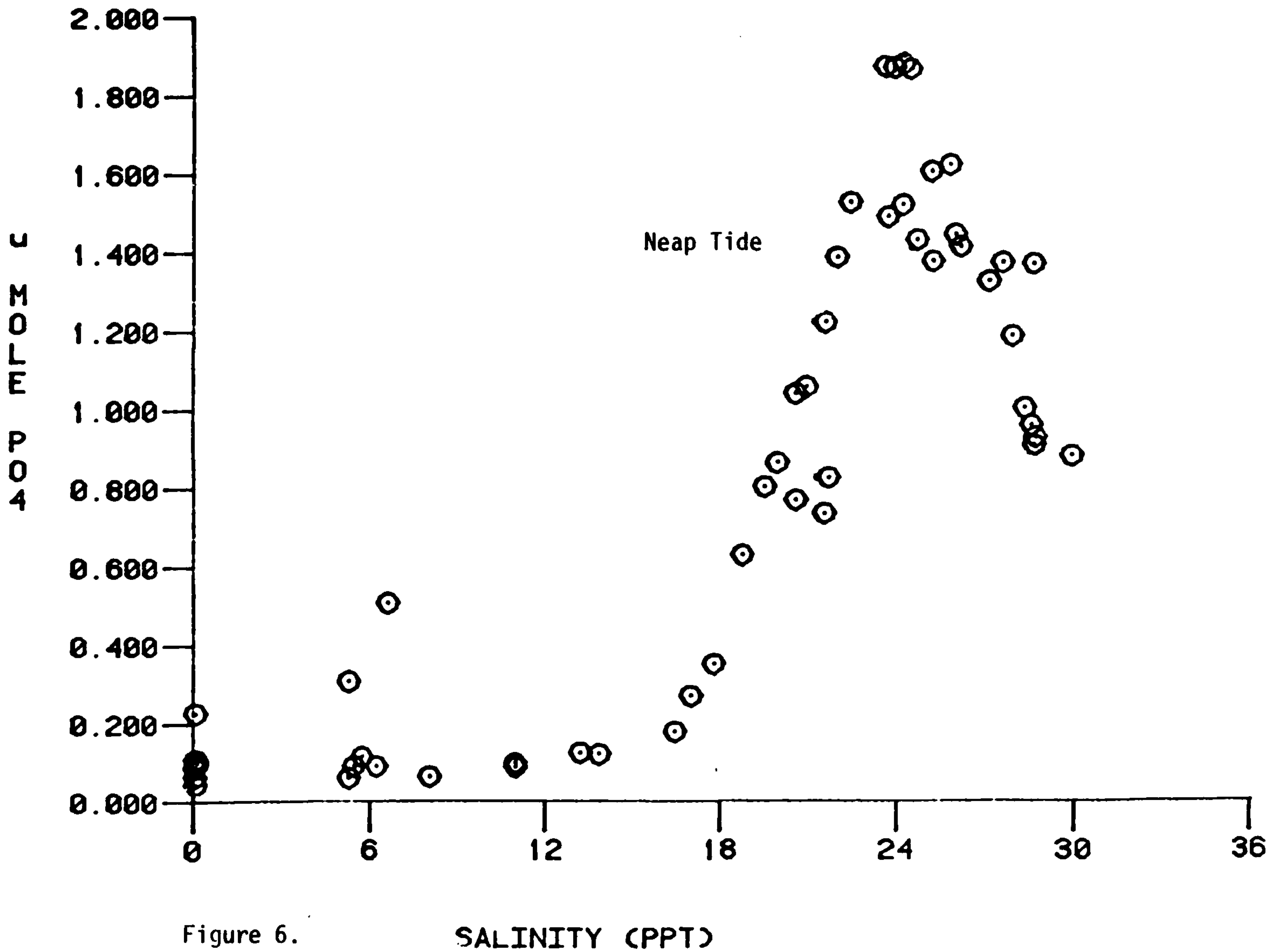


Figure 6.

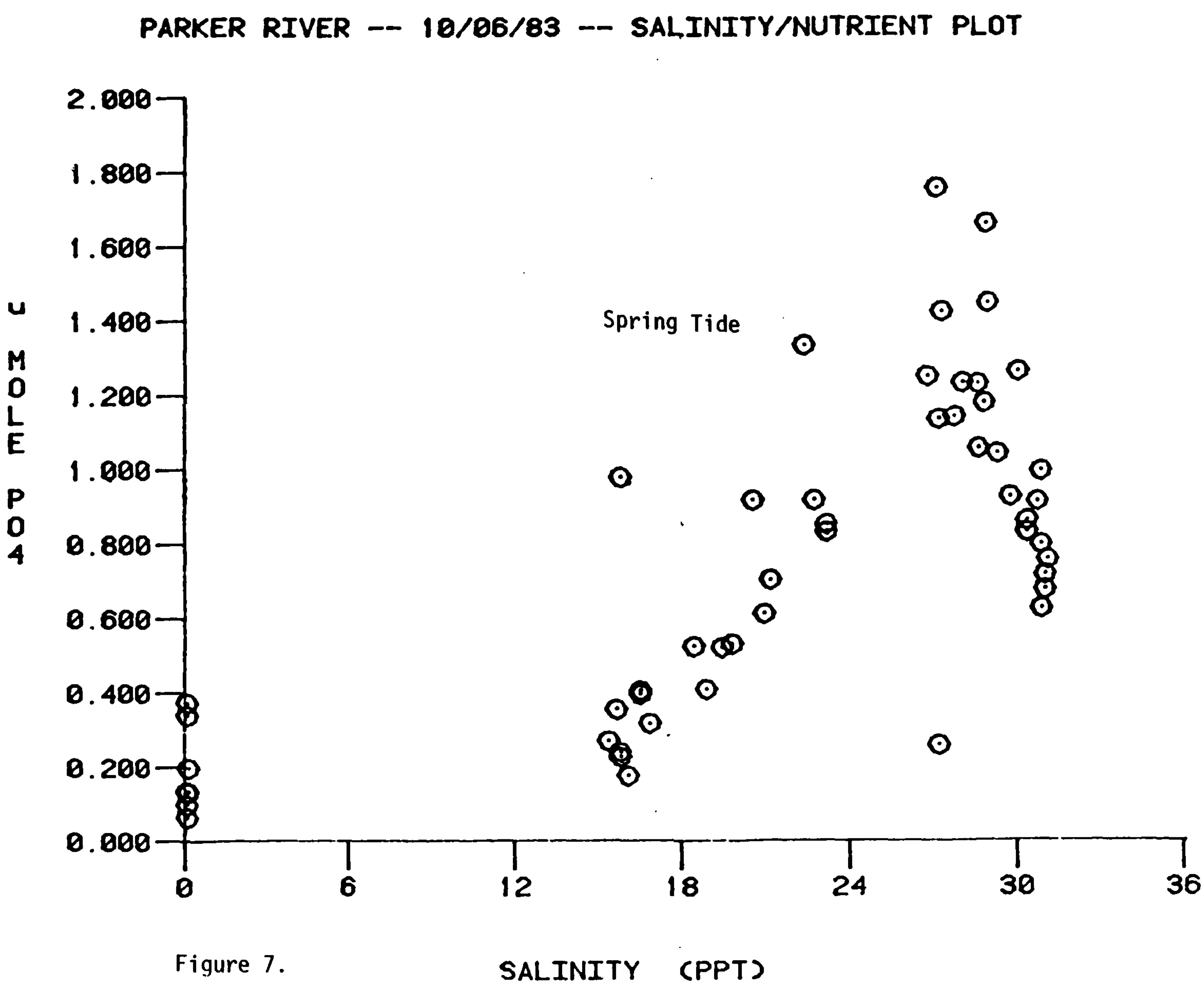
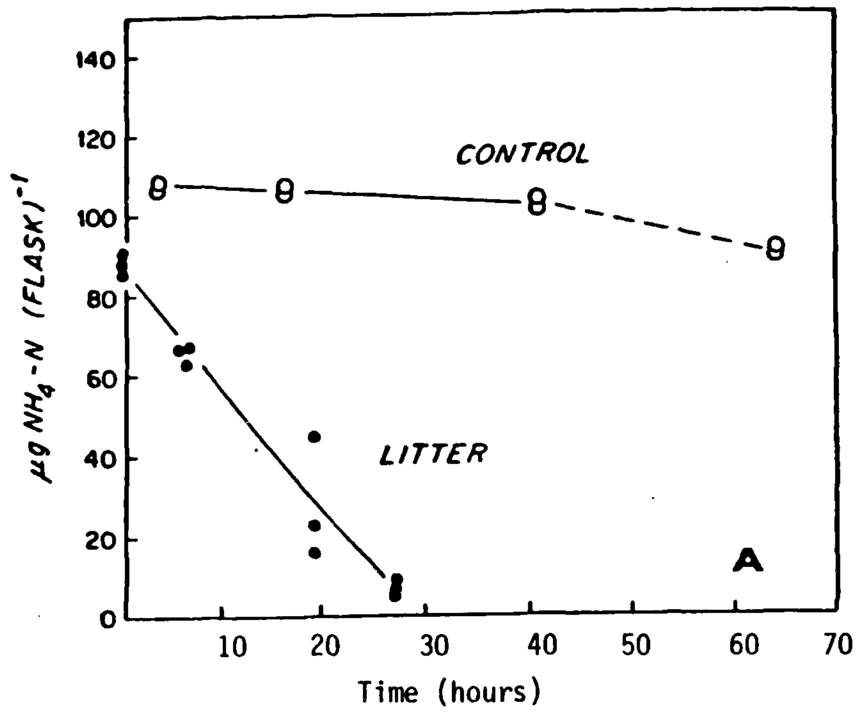
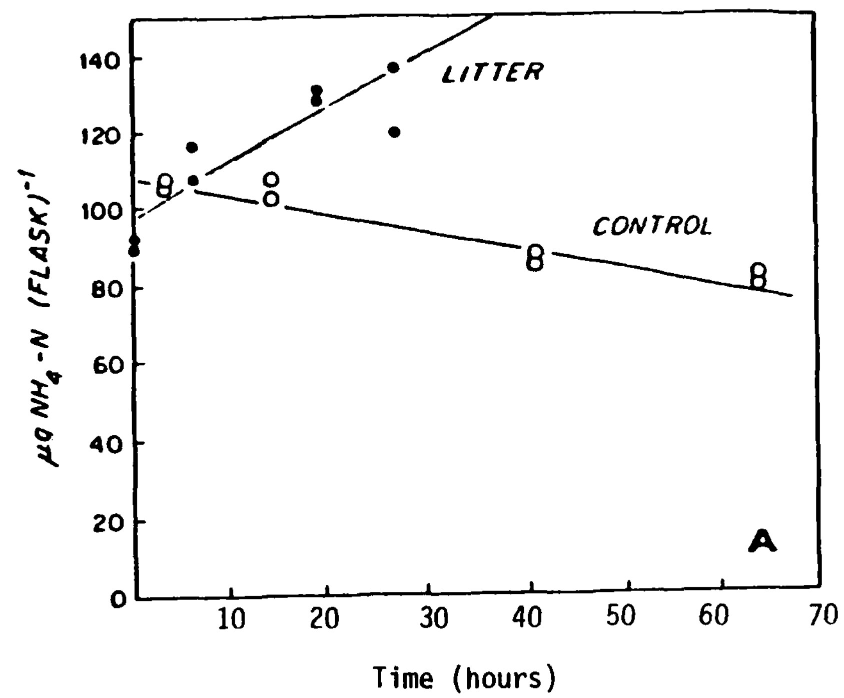

PARKER RIVER -- 10/06/83 -- SALINITY/NUTRIENT PLOT
u MOLE PO4
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
Spring Tide
0
6
12
18
24
30
36
SALINITY (PPT)

Figure 7.



AEROBIC



ANAEROBIC

MARSH LITTER INCUBATION EXPERIMENT (from W.B. Bowden. 1982. Nitrogen cycling in the sediments of a tidal freshwater marsh. PhD Thesis, North Carolina State).

FIGURE 8

AD-A161 134 NEW ENGLAND REGIONAL COASTAL ENGINEERING CONFERENCE (1ST) HELD AT ROCKPORT MAINE N 30 OCTOBER-1 NOVEMBER 1984(U) CORPS OF ENGINEERS WALTHAM MA NEW ENGLAND DIV 3/3

UNCLASSIFIED OCT 85 F/G 8/3 NL

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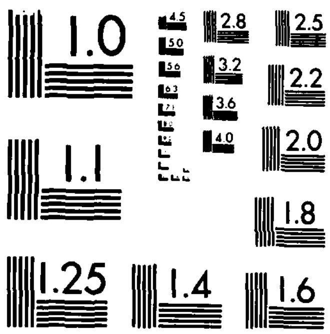

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE I -- N BUDGETS TABULATED BY MODEL

	MEASURED (kg)		INFERRED BIOTIC EXCHANGE (kg)
JULY 1980	Flux In	Flux Out	
NH_4-N	1.4	2.1	0.7
JUNE 1982			
NH_4-N	22.3	31.2	8.9

THURSDAY, NOVEMBER 1, 1984

8:00 a.m.

INDEX

PANEL DISCUSSION: PAGE

P R O C E E D I N G S

MR. BRUHA: Good morning again. It kind of seems like we haven't left here. Last night we were a little late, but it was worth it. I want to thank everyone for showing up last night. I especially want to thank the speakers. I appreciate those of you who took the time to come and listen, and participated in the evening session.

Unfortunately, when you have these meetings you really don't have enough time to get everyone involved, because of the limited time involved. There isn't even enough time for us to visit. We should probably have had yesterday afternoon's session out on the patio, because it was so nice.

A couple of reminders. Number one, there is a questionnaire available that we'd like to have you fill out before you go. Jim Doucakis will pass it out now if you haven't already got one. It's important that we get a little more feedback on exactly what you're feelings are about the conference, whether we should have another conference, where it should be, how often we should have it, and what are some of the topics you'd like to have discussed by whoever has the conference next time.

You notice that we've stayed away from the word annual. It's the first regional coastal engineering conference, not the first annual regional. Just a reminder, that's all.

Another reminder, check out time I understand is one o'clock. So keep that in mind.

Today's session will be handled very similar to what we have been doing, with only one variation. If you look at your agenda, you'll see that there are five or six related topics that we'd like each of the speakers to briefly address, maybe five minutes. We will then open the discussion up to questions and statements from you.

I want to remind you once again that this is not a decision making conference. This is an information conference. We're trying to gather information for future decision makers to look at on the issues we're talking about, so that maybe somewhere down the line they can say, well, should we cover these issues or have they been covered. And we're looking for your input. This is your day. If you feel that you have something to contribute, or you want to make a statement, or you want to just come up and say, hey, you guys, let's not have any more of these because it didn't pertain to what I wanted to hear. Let's hear from you, because this is your chance to do your thing. We have extra slide trays if you want to show some slides.

I ask that you, please, don't get into a detailed question and answer session with the panel members, but if you should have a question relating to his topic that you haven't had a chance to ask, please feel free to do that. That's what this session is all about. We'd like to have you give us some input and some of your feelings about exactly how you feel, and the direction we should be going or someone should be going in the future on these issues. And if we could get this information out of the conference, I feel somewhere down the line we've accomplished our mission.

At this time I would like to introduce the Deputy

Chief of Planning, Mr. Nick Avtges, who will handle the discussion sessions. Nick, you can handle them either from where you are or come up here to the mike; it's up to you.

The other thing is that I think the accommodations here at the Samoset have been absolutely spectacular, and I would like to thank everyone involved at the Samoset for making it so comfortable and convenient for everyone. And I think maybe it would be nice if you're happy with the accommodations. When you signed out, you may want to say something to the desk letting them know that you were happy with the accommodations or, maybe write them a note or a letter expressing our feelings.

I think without further ado I'll turn the microphone over now to the moderator of the first session who is Dr. Ken Fink.

PANEL DISCUSSION - BAY OF FUNDY

DR. FINK: Thank you, Tom.

The title of our first session this morning is going to be the Bay of Fundy and that has more to do, I think, with the tidal project obviously and the impact of that on the Gulf of Maine shoreline. To structure this session somewhat, there are a list there of five items that we'd like to have discussed in this session: Identification of the issues, summary of the major problems and concerns, the efforts that each of the participants, including you, might see as a contribution towards the solution to the problems and so on.

And I think in order to get this going a little bit, Bryan Pearce has volunteered to give us a very brief account of his upcoming project funded by Sea Grant that's going to take a look at the Greenberg model and attempt to do a 3-dimensional approach to this. So we'll start the session off with Bryan Pearce.

MR. PEARCE: I'm Bryan Pearce, as Ken said, and I'm at the University of Maine.

Because of sort of the political furor and hue and cry about this famous one foot increase in the tides, I thought it appropriate to go ahead and look at the problem. And I submitted a proposal to Sea Grant. It's made it through the peer review and one thing and another, and it's fortunately going to be funded. Now, we've actually started working, although the funding will start in January. It will go for three year, and as I'll mention, there are several projects that go a wrong it. One at the university of New Hampshire.

I think you've seen all the stuff, the top three red hands there, sort of the sensational part of this stuff. At the bottom here is another what I think is very important part of the problem, and that is that in addition to looking at the tides in the Gulf of Maine, the circulation is of interest for a variety of reasons, and there is still a lot we don't know about. So I think the project will in that sense serve two purposes.

So the things that we want to do, and I think somewhere up there that says Project Objectives on the top. Obviously a major part of the project is to look at the tide and the circulation in the Bay of Fundy/Gulf of Maine. I noticed someone had a slide that said Gulf of Mexico, Bay of Fundy/Gulf of

Mexico.

Now, Dave's model basically examines the barotropic response, the tidally generated response. In addition to that, of interest possibly with regard to the tides and certainly for general interest is the baroclinic or the density driven circulation. And so what we're proposing to do is to look at both separately and then combine them.

Now, another important part of the project is to coordinate with other people who are working on the Gulf of Maine. I've been working with Dave Brooks now for a couple of years, and he's an Eastport native originally, now at Texas A&M, and has been doing quite a bit of splendid research primarily taking synoptic density observations. He's trying to look at the circulation where the water masses and the water comes from and goes to in the Gulf of Maine.

Wendall Brown at the University of New Hampshire as part of their Sea Grant program, has a new fairly large project funded to take a long time series vertical profiles of density and also pressure at the bottom. And one of the things that will help us do is to look at the flows, particularly the flow in the northeast channel. When we start looking at the density driven circulation then the flows in and out of the basin are, of course, going to be very important.

And then finally, we ought to Collaborate with Dave Greenberg since he's been doing so much work for, I guess, ten or fifteen years now, a life's work practically. So I think that's the other things that points out that this is not a trivial exercise actually. It's a relatively involved problem. And one of the things I hope is that this will sort of get us started. The funding is enough to have several people working on it but it's not an incredible amount of funding.

And finally, it's probebly appropriate, although possibly trouble, if the University of Maine and University of New Hampshire, if these project sort of serve as a base for studies, general studies in the area.

Now, the next transparency. I call this slide "Details". So some of the things we want to do, as Jim Houston mentioned yesterday, one of things that is probably appropriate is simply use a different model. In other words, I think the basic physics is probably a foregone conclusion, at least the first order part, and so the questions that typically arise if you're doing numerical modeling will be of this kind, well, gee, is it coded properly, are there errors in the code, so on and so on, and how do you know. Well, you don't really know for sure.

So one of the things to do is perhaps try it differently and see if you get the same answer. If you do get the same answer, then you're still not positive, but you feel a lot better about it. On the other hand if you get a different answer, then you may have to go back and say well, let's go for three out of the five. Or try to find the errors.

And then, of course, I mentioned the barotropic versus the baroclinic. Dave Brooks in particular, Jim Houston of course stole those quotes from my proposal. That's an unpublished thing by Dave Brooks, by the way. Dave is particularly concerned about the importance of the baroclinic circulations since the friction is a nonlinear process, and if there were sort of density

driven net circulations, they may in fact affect the over all dissipation and change the tide levels. And so that's one of the things, of course, we want to look at. And then the next two red hands there point to sort of the red herrings in the problem, the grid scale and the effects of the ocean boundary which maybe these people talk about later, maybe they won't.

The next slide, on the bottom, you'll see a red star, and then you'll see two red pluses, and those are where Wendall Brown wants to put out his conductivity and temperature strings, and what he'll be able to do at least roughly is between those stations and then between the shore stations, you can time into the shore stations and get some estimate of the net flux, the net water flux between those points.

So that's part of where we go from here, at least one of us. A few of us will be starting to work on the problem.

DR. FINK: Thank you, Bryan.

Our panel up here then we'll ask them to summarize what they see as either priority areas that we should proceed with or what they see as concerns or even just a comment or two on what they see is as the next step we should take for this Bay of Fundy problem.

Who wants to go first on that? Dave, you're first in line so I'll let you make your comments.

DR. GREENBERG: What needs to be done. Somewhere along the line you're going to have to be convinced of what the order of magnitude of the changes in tidal regime from a Fundy tidal power plant are. I don't know how appropriate it is for a Canadian to tell you exactly what to do. I will tell you a little bit of how I think it might be done. You could take the approach of sensitivity testing, saying let's keep kicking this model until we're sure that every time we kick it, it goes in the direction that we think it should go. Or you could take the other approach of doing other models. And then either way would probably give you a useful result. And if you're trying to be absolutely certain, you might want to take both ways. All of that can be done.

I do want to repeat that I did say order of magnitude of result. If you're really after the last two or three centimeters in accuracy, I don't think you're going to get it. If that is necessary for viability, then to me by definition no longer is the scheming going to be viable. You're going to have to be able to work with saying is a four or five centimeter change important; is a 10 or 15 centimeter change important. And if it's 15 and not 16, if that's critical, then my bet is that somewhere along the line in Canada they're saying there's too much risk, we're not going to build it.

If you are going to do some new modeling then I do have some suggestions. That has to be done right. It's probably not a good idea to repeat exactly what I've done, but there should be some improvements. For instance, if we take a look at the grid in the head of the bay, you'll have to have a resolution at least as good as that in Minas Basin. This is the lower end of the slide. You're going to have to define that area very well and in particular that small channel around Cape Split, my experience has been you're tides don't start to be reproduced accurately, using reasonable parameters, until you've got that resolved. And that

is minimal resolution right there.

If you're going to try to do a better job, then you're going to have to go to even finer resolution. The problem there is that if you're using your standard CFL criteria for time step which dictates how long it's going to take on a computer, the whole model time step is determined, at least in my model, by that very deep area which comes through that channel. That's about 60 fathoms deep which is quite a deep area for a small grid size.

Note in particular also the upper grid. We've all been talking about the 15 centimeter change in Boston from the barrier in this Minas Basin area. There is a very good chance and maybe even the chance is favorable that the first barrier built, if there is a barrier built, will not be the lower one in Minas Basin but will be the upper one, across the mouth of Cumberland Basin.

If that is built, then you probably don't want to take immediately the answers as to what's going to happen in Boston or anywhere else from the existing model. The resolution is at best fair up in that area. It is predicting changes in Boston, I believe two to four centimeters. Small beans perhaps, but still something that you might want to check. Is that going to affect things adversely? First of all want to refine that end of the model and do a better job up there.

You do want, in the upper end of the bay the full set of nonlinear terms, all interacting. They are necessary even to look at the first order tides. Some of the later work I've done with the nonlinear terms everywhere, I don't think that's absolutely necessary just to look at the tides. But if you are gone getting into second order of effects like residual circulation, the sort of the thing that Bryan Pearce is doing, then yes, you do want all the nonlinear terms and that sort of the thing.

There are existing models that will give you almost order of magnitude sort of answers. Already Bryan's got one, Spaulding has another, and I'm sure that the -- well, I don't know the Army Corps of Engineers modeling. I assume that it would probably be useful to. What approach you want to take. If you want to take all of the approaches. You have to put it through a good review and make sure everybody is happy that what is coming out is what you expect and what you believe.

From there, once you've got your order of magnitude results, I think what you have to have then is site specific studies, and this is where really most of the work remains to be done. Is 15 centimeters important? Is 4 centimeters important? Is 15 plus or minus one centimeter important? Is 15 plus or minus 10 centimeters important? You have take into account what you think the accuracy you're going to get out of your results and give them that. Is that good enough to figure out what you think might happen in all your processes?

You have to do site specific studies. You have to do process specific studies. They aren't going to be, I don't think, on the grand scale of the whole Gulf of Maine all at once. They'll be looking at Penobscot Bay. You'll be looking at Booth Bay Harbor. You'll be looking at all these little places one at a time until you get a feeling that says, okay, now we can generalize. We know what's happening in this harbor. This harbor

is somewhere between harbor A and harbor B in it's characteristics, and we think we know what's happening in both of those, so somewhere between this is what's happening in harbor C.

That I think is the way you've got to go. You've got to look until you understand the small systems and how they're going to change, and if you're lucky, you'll be able to generalize without having to do every harbor and every beach and every rock face that abuts the Gulf of Maine.

One of the studies that might be done with a large model that might be a little bit farfetched, but you do want to figure out what happens when you do close the barrier, how quickly it is going to change the tidal regime. As Peter mentioned earlier, that is a little bit up in the air as to whether the effects are going to be felt over a few months or a couple of years.

Another very related effect is can you mitigate some of the bad effects of the higher high waters, perhaps by barrier operation. If you do a good weather prediction with a good storm surge model, if you predicted a surging coming in to swamp Logan Airport, could you then say, uh-uh, let's open all the barriers, all the turbines, all the sluice gates, and sort of trap the reflected surge at that end, or put another one through that will put a surge ahead of the high water or behind the high water that would mitigate this circumstance. It's a little bit farfetched, well maybe not farfetched, maybe perhaps grasping at straws would be a better way of putting it. That sort of the test remains to be done, and it might be something that would mitigate at least some of the extreme high water worries that we have.

I think another way we could be going, if I could pull out a Canadian example, where the people found -- there were a lot of people like the people in this room in Canada who were interested in working on the Bay of Fundy, and what they did do is they said we're going to get together every year on a regular basis just to talk about what we've done, and it turned out it to be a very good cooperative effort.

There is a book out now that sort of the summarizes this effort, available free of charge, an Update on the Marine Environmental Consequences of Tidal Power, The Developments in the Upper Reaches of the Bay of Fundy is sort of a summary of everybody's work, as the Canadians have done it. It's more oriented towards the upper end of the bay. This is available free of charge if you contact Don Gordon of the Bedford Institute. He'd be happy to give you a copy. It is a useful summary.

I think it would be a very useful example for people here I detect, with the competitive nature of American science, that a lot of people are afraid to talk to each other for fear of stealing ideas and stealing grant money one way or another or duplicating. This in Canada is not quite the same problem. And so we've gone on to get together, and the cooperation is ended up, I think, with a much, much better product over all. And I think if you can manage to get yourselves together often enough and talk to yourselves openly enough, that you're going to find that the talent in this room is already sufficient to give you a very good solution to the problems you want.

I guess just summing it up, I guess what we want to do is be sure we do everything right, and as long as we are doing

everything right, we will avoid the ultimate wrong thing to do and that is at the end if we have to say, Whoops, we've done it wrong.

DR. FINK: Thank you, Dave.

Jim, do you have have some comments you'd like to make now?

DR. HOUSTON: Yes, I'd like to briefly discuss one problem. I will say a few preliminary things first, these are just my opinions. I think that the Canadians are not going to build a power plant unless there is a guaranteed user of the power. I don't think they could arrange the financing. The U.S. would be the main user of that power. I don't think the U.S. would agree to guarantee accepting that power unless the consequences of the power plant are known ahead of time in some detail with some degree of assurance; this means there are are a number of studies that are obviously going to have to be performed before the U.S., I think, would guarantee to accept the power.

Now, we know the Canadians have done great detailed studies in the upper Bay of Fundy, I suspect similar types of studies are going to have to be performed in the U.S.. We've discussed some of the hydrodynamics studies. I think that's really the tip of the iceberg. The major studies would probably be environmental studies, resource impact studies, geomorphological studies of beaches, salt marsh response, and so forth. These have to be very detailed studies. I think probably requiring significant funding. I think therein lies the problem.

In order for those types of studies to be performed, and I think they would have to be U.S. performed studies, policymakers in this country will have to be convinced that the Canadians are serious, and I don't think at this point that this is true. There are some people that have quite an interest, for example, Senator Mitchell of Maine. I think he's had great difficulties in convincing other people in Congress that there really is any significant chance that the Canadians are serious.

So basically if the Canadians really are serious that there is a fair chance they are going to go ahead with this project, that somehow has to be conveyed to policymakers in this country. I don't know who does that. Maybe some of the people in this room, the Canadians. I don't think it's been done at this point. Because these tidal power things have come up in the past and they have tended to disappear, I think a lot of people in Congress just assume that this will come and go like everything else.

We do have an advocate. As I say, Senator Mitchell is very interested. But I think he's going to be unsuccessful in convincing other members of Congress unless more people are convinced that at least there is a fairly serious probability that the Canadians may want to go forward.

So I think that's a major problem. That's more of a policy type problem, but I don't think you'll see significant fundings of the type like the Canadians spent in the upper Bay of Fundy coming from the United States unless some of the policymakers in this country are really aware of the problem and see some sense of urgency.

DR. FINK: Thank you, Jim.

Next on the list then is Peter Larsen who has some comments, I know.

DR. LARSEN: Thanks, Ken.

I'd like to begin by commending Dave Greenberg on his remarks. There was an awful lot of wisdom in those remarks, wisdom that may not be spoken by competitive American scientist. But I would suggest that when the proceedings come out that you reread those comments. There is an awful lot of food for thought there.

Speaking this morning as an ecologist, I'd like to say that rather than ask where do we go from here, it might be more appropriate to ask where are we right now. Jim Houston has just addressed some of that, and there is a reality in what he says. I believe right now that we're just at the advanced stages of recognition of the issue; that is, the general issue of Fundy tidal power, and possible tidal regime changes in the Gulf of Maine.

There's been some discussion about this issue for at least five years now, but it's only in the last year and a half that any serious response has come from those discussions. I think the good turnout and the spirited discussions at this meeting are evidence that the general issue may be reaching a certain critical mass, but what remains is that our understanding of this very complex and far reaching issue is still embryonic. Before we go crashing off to do some expensive research, it might be prudent to give some consideration to things that really need to be known, to what answers are already available and to what questions can be answered with data already in hand. A number of the issues that have been raised I know either have been answered or can be answered in a short period of time with existing data for modest cost.

As a starting point for any consideration of where we are, I offer two publications, the one that Dave Greenberg held up that's available from Don Gordon at BIO, another called Fundy Tidal Power Development, Preliminary Evaluation of Its Environmental Consequences to Maine. This is by a bunch of very fine people, and was funded and printed by the Maine State Planning Office.

As the title suggests, the Canadian publication does emphasize the upper reaches of the Bay of Fundy but still it gives you quite an insight into the scope of the project and some of its ramifications and to some extent does address far field effects.

The second document, as the title suggests, is a scoping study. It's purpose is to document or identify areas of legitimate environmental concerns and where possible to make just first cuts of the magnitudes of possible consequences or impacts. It was not intended to be an ultimate answer to anything, but only to bring visibility to the issue and to begin a discussion. I think in those regards this report has been successful. But it's only a first step.

I would suggest now that there is a greater visibility of the issue, and there are people from many more disciplines involved in the issue, that it's time to go to a more rigorous scoping study. I would suggest a well-defined effort by world class experts in each of the fields or subfields where it is presently perceived that there is a problem. I think this could be done very quickly, and it would produce well-defined research directions, and even plans at state of the art levels. The result

would be that a lot of money and, perhaps more importantly time could be saved from going off on false starts or spending a lot of money in insignificant areas.

Now, I'd like to make two more specific comments on the practical side. As I said yesterday, I think it's important to start the environmental work as soon as possible. Even though we do know a lot now and probably could double, triple, actually increase our knowledge an order of magnitude within a year or two, some of the very important questions that have to be answered are going to take longer time period, perhaps five to seven years, and that timeframe is longer than the engineering, i.e., the precommitment studies that are needed for construction to begin. So at the very best, the environmental work should start two or three years before the engineering work, and by engineering I just mean planning, not the construction.

But even more so, ideally it should start five to seven years before so the results of the environmental work can be worked into the engineering plans. That's something that doesn't often happen and we still have the opportunity to do that. I wouldn't be too concerned about the question of suppose we do all this work and then the answer is no, we won't build the dam. For one thing, the proponents or the perceived proponents have stated publicly that they believe the economics are so good that it's a question of when, not if, the tides of the upper Bay of Fundy will be harnessed. In addition, because the tides are such a basic forcing function in the Gulf of Maine, this is research that needs to be done anyhow whether you're talking about tidal power, sea level rise or problems with fisheries. It's basic research that should be done.

Finally the question of verification of the Greenberg model. Obviously if I'm speaking as an ecologist, I can't say very much in detail on that. But I think verification is important for psychological reasons, for political reasons, but again not necessarily for ecological reasons. The research needs to be done. The question isn't whether it's going to be 5 centimeters, 15 or 16; we're talking about changes in tidal regimes, and the kind of predictions that I think would be sufficient from an environmental point of view aren't going to be that precise. You want to know directions of change and general orders of magnitude, and we have enough information now to go ahead with environmental studies in that regard too. I think I'll stop right there. Thank you.

DR. FINK: Thank you, Peter.

And finally then, we'll hear from one of the state agencies, David Keeley from the State Planning Office who has been a coordinator of one of the efforts in the State of Maine for all the research and associated activities that have taken place here. Since the revelation of the impacts of the Bay of Fundy tidal dam on the State of Maine.

MR. KEELEY: Thanks, Ken.

Yesterday I talked a little bit about several things, and I'd just quickly over those again. We've talked in a number of meetings like this about the need to take this International Joint Commission, that there's definitely a need to get this into an impartial, bilateral form.

Yesterday I also mentioned accuracy of model and

verification. And as Jim suggested, until the model is verified in whatever manner is appropriate, I suspect that there will not be significant amounts of funding available for researchers and others to pursue the various impacts or consequences of the project. And therefore, I think it's only prudent that we address the issue of verification and whether Bryan's work that he talked about earlier would succeed in doing that or not, I don't know, but from a policymaker from state government perspective, until such time as there is a consensus that the model has been verified, that the consequences identified by David are indeed probably what we should expect, I doubt whether there is going to be adequate funding to look at the various issues raised.

This meeting and others like it reinforce the notion also that we need to identify some sort of group that would be responsible for being the lead in coordinating both the gathering of scientific information and disseminating information, and there has been some discussion whether it should be federal agencies or state agencies. Unfortunately I don't have a suggestion to make. But we need to identify a group that would be responsible for doing that as well.

Jim mentioned and so did Peter the fact that it's again only prudent that we allow ourselves adequate time to look at all of these consequences, and right now it seems that there is an enormous amount of time, and I dare say all we need to do is have the Persian Gulf mined again or our oil cut off.

DR. FINK: I saved David to the last because there is always great interest in the possibility of funding for research of any topic. And I think there were two points made there: One, as David said, there is simply not going to be a great deal of money forthcoming until all the verification of the Greenberg model. Is there something to worry about or not?

On the other hand, as Peter says, I think there are a lot of people, I know here from the University of Maine, from Bigelow Labs, various other institutions that have done a lot of work along the coast of Maine already as well as Massachusetts, those areas that will receive the most severe impact of this, and as he suggests it's prudent for us to perhaps to take a different look at the work we've done already in the context of the impact of the Bay of Fundy dam. And that's work that I don't think necessarily needs a great deal of support in terms of funding. It's simply going back over the information you have and looking at it in a somewhat different framework. And as Peter suggests, that something we can all get to work on right away. I know this has happened at least in my case and I know in other people's cases already. So I think your suggestion, Peter, is a very good one.

At this stage we're going to be turning this over to Nick, but before we do, I have a tape that I've been requested to play and Dr. Baer is back there, who is going to introduce this tape, and then I'll plug it in for everyone to hear.

MR. BAER: This is just a copy of a national public radio presentation on the Bay of Fundy with several of our people stars on it, and I suspect some of them haven't even heard themselves on it. It was played in Washington, D. C. on October 14th. I don't know just when it was played other places, and it isn't very long and I think you might find it kind of interesting.

DR. FINK: Thank you. I haven't heard this yet myself. My wife told me about it. Les Watling told me about it and I've been dying to here it, so I'm delighted to hear that's what it is.

(Tape played.)

DR. FINK: Very interesting and very entertaining. It's always nice to hear yourself, isn't it, Peter? Do you have any last minute words?

DR. BELKNAP: I'd like to know if Dr. Greenberg's computer is listed as his co-author? (Laughter.)

DR. FINK: At last they've come alive. Peter does have a comment.

DR. LARSEN: Greenberg, greenhouse, what's the difference? It did remind me of one point this rebroadcast. That's an awful trick, Lee.

One thing that could be done and perhaps should be done is a comparison, a real comparison of the environmental costs of this much tidal power versus the same thing, whether coal fired, oil fired or nuclear plant. We gather at meetings like this and you start talking about scientific things, and it gets sort of self reinforcing and then the press goes and uses words like "disaster" and "opponent" and all that stuff. It kind of loses its scope. I think if we sat down here and talked about 4000 megawatts of coal fired power and tried to catalog the environmental effects, increases in lung cancer and what have you, it will also sound pretty disastrous. But that one-to-one comparison between this method of generating electricity and others has not been made, and I think it would be very insightful to have done.

DR. FINK: At this time we'll turn this over to a public discussion of the consequences of the Bay of Fundy, and to handle this part of the discussion, I think the panel members will stay up here, as I understand it, and Nick Avtges will handle that part of it.

MR. AVTGES: Thanks, Ken.

Before we open it up for my discussion, I'd like to give a little Corps perspective and I'd like to go through the five items that were listed. And the first one, identification of the issue. I can personally relate to it whether its significant or insignificant. As a nonswimmer, from the chin to the nose is significant; but as Deputy Chief of Planning, some planners may think it's not significant.

We've learned the last couple of days that with time and money we can come up with the right answers. And this leads into the major problems and concerns. As far as the funding that Jim Houston addressed, Senator Mitchell did manage to get legislation in a Senate Bill, Senate 1739 known as the Abner Bill, which authorizes the Corps to direct such a study. It wasn't a $10 million study. It was broken into a 2-part study where the first part, which I guess the costs were one to two million, would address the items that Peter Larson was mentioning earlier of how do we get to where we want to go, and what has been done. Reviewing all the effort that's been done to date. And if an additional research and study is warranted, then we would proceed into the much larger study, and the original estimates were in the neighborhood of $10 million.

The efforts each participant sees as a major contribution towards the solutions to the problem, well the Corps has the resources. We heard representatives of our labs that have done work that could assist in studying the impacts of such a large venture. As far as the Corps is concerned, we have a federal investment, there are 130 to 140 navigation, beach erosion projects that I don't have the dollar amount available, but there have been millions of the dollars of federal funds spent along the coast, and we sure would like to know the impact on them and what modifications and costs are associated.

If the Corps is directed by the Congress to work on such a study, it has to be made clear that the Corps cannot do it alone. It has to be a combined federal/state/public/private/ independent labs, everyone would be involved. And we feel the Corps has the resources to manage an independent study to come up with the answers. And we would anticipate from everyone in this room, we would get the cooperation and participation, and I'm sure most of you would be asked to provide input to such a study. Again, provided the that the Corps manages it.

That's it in a nut shell from my perspective, the Corps perspective. We can open it up for general discussion. If you want to ask the panel any questions or make any of your own comments, feel free to do so.

MS. SPILLER: We've heard a number of people say that verification of Dr. Greenberg's modeling is the critical first step in getting more funding and developing studies in this area. I'm a little confused because I've heard that the Corps has several models that they've suggested that could be used to this end. I gather that NOAA has a model, several models. Bryan Pearce has a model. Malcolm Spaulding has a model that may be applied to do this.

David Greenberg already has a model which perhaps with more refinement and fine tuning could give us a better sense of numbers in this area. I wonder if anyone could suggest how we can develop a strategy to either bring all these models together or create a hierarchy to figure out how we're actually going to go about verifying the models.

MR. AVTGES: I'd like to ask Jim if he can respond to that after I make a comment. The Corps will not get involved until we get authorization and funding. The Abner Bill had the authorization and then subsequent appropriation bills would have provided us with the funds. The initial effort, I think it was 1.3 million, did include funds for the Waterways Experiment Station to get started on the validation of the model. And, Jim, if you want to add to that.

DR. HOUSTON: I'm not sure just how to respond to that. When funding becomes available, I think the experts in this room in numerical modeling, I think, would have to form some sort of group that would work together. I think any kind of calculations you'd want consensus on the approach taken. I think that would have to involve Dr. Greenberg and probably all the people that were mentioned including dissipation by NOAA at some kind of an oversight group or technical group.

MR. AVTGES: Are there any other comments, questions?

DR. KELLEY: My name is Joe Kelley. I work with the

Maine Geological Survey. I think this would be an interesting and difficult problem to address; that is, the impact of a change in tidal range at least from a geological point of view if it were to impact Delaware Bay or Chesapeake Bay, fairly maturely studied regions. For sucn an event to take place in the Gulf of Maine, an area that is considerably larger and much more poorly understood is vastly more difficult to resolve. Pretty clearly what is required in the Gulf of Maine is the collection of more basic scientific observations, rather than necessarily an applied project.

Two general problems that confront one when one is trying to do that is obtaining long-term sources of funding, which is what you've just addressed, so that one doesn't spend dreary days and nights writing proposals to funding agencies that want to see really jazzy cutting edge of science sorts of things, when really the collection of basic data has been lacking in the Gulf of Maine.

Similarly an organizational framework for the disposition of the funds is presently lacking. Personally I have no difficulty with the Army disposing of funds, and there are probably other agencies that could do so. But it's not clear how that will be achieved.

It's pretty clearly a multidisciplinary problem in the sense that geology, biology, chemistry, physics, engineering, and so forth, are discipline to be integrated into any sort of study. I don't think it's a hopeless problem. There are organizations, the Estuarine Research Federation for one which regularly has meetings and individuals from many discipline come together to study estuaries in a multidisciplinary sense.

The major difficulty that I would see, however, is not getting individual scientists from different discipline together but rather people from different organizational frameworks -- federal, state, university, private sectors and so forth. It's very hard to integrate these agencies when in many respects many of them are competing for the sources of the funding that would be better spent in a cooperative fashion. Thank you.

MR. AVTGES: Any other comments? Questions?

DR. BELKNAP: Dan Belnap, University of Maine. One thing I haven't heard in the discussions so far is when we get to the end of the planning stage, presumably if the project is built, there will have to be a mitigation stage. There will have to be some sort of compensation or some sort of engineering approach to coastal erosion problems. I'm just talking geological not biological right now.

It's been proven in the past that engineering solutions sometimes aren't the best. The Corps of Engineers is coming around to the point of view in some cases that it's best to leave inlets alone and leave beaches alone. And in particular on the Coast of Maine, seawalls, for example, are no longer allowed. And there is a sand dune regulation that regulates the coastal zone. So I wonder if we're thinking in the proper terms about engineering solutions to this proposed problem. Perhaps we should be thinking in terms of coastal set back laws, compensation for property owners and that kind of thing. I think that should be discussed, and I'd like Dave Keeley and Jim Houston perhaps to comment on that if they could.

MR. KEELEY: We discussed a little bit at breakfast this morning about compensation and a number of topics have come up. For instance, FEMA currently supports coastal developers and land owners. And how would one determine that this 6-inch rise was attributed to the Fundy project versus something that ordinarily like would have happened anyway. And clearly organizations such as FEMA need to look at what the consequences of a 6-inch rise would be, identify in some manner how the flood insurance program would be affected by it, and seek compensation, a one-time compensation that would go into a fund that would allow for homeowners to be compensated in the event of flood damage.

I would say that there has not been very much discussion on compensation. I'm not sure mitigation is really the right word. We're looking more towards compensation, and George Baker in the public hearings we had in Augusta said that there would be compensation, and it's difficult to set aside funds for compensation when we don't even know in reality what the effects are going to be.

DR. HOUSTON: I don't think I really have anything to add, except that at some of the previous meetings Mr. Baker has talked a little bit about compensation. There may be somebody here from Canada who may want to speak further on it. I think there was some indication that maybe there would be compensation up to some fixed amount, some maximum compensation. So one of the problems would be, you'd have to assure yourself that the consequences would be less than that maximum compensation or you might have some problems.

DR. GREENBERG: I'll try and pass on my perception of George Baker's views, and I think his ideas there are that along the lines of any type of energy is going to have problems in environment or anything else, and the idea is that if there are problems, they have to be at least compensated for.

I think compensation, although it might have been the only word used when people here have heard him, I've also heard him talk about some types of mitigation where they are trying to perhaps build enough seawalls and this sort of thing might be the sort of thing that they would also get involved with.

He tends to think that if there are problems, there is no way Canada will be able to escape from paying for them. They may ask for some partial help from the people that are using the power in that they are getting part of the benefits, they might accept part of the risks, and I'm can't remember but perhaps that capping of the amount of liability might be part of the risks.

As for the collecting for the monies, he figures that if there was some problem that could be attributed to tidal power and the money in the States is there to pay for the power that is coming from Canada, he figures that that could probably be stopped before it crossed the border and wouldn't be that difficult for a lawsuit in the States to be held. I think that might be the sort of idea where he would like to see some sort of special legislation, some sort of special board set up that would decide on on a once-and-for-all basis is this a proper claim or did the fact that this fisherman not get in on time in high water, really is that a compensatable claim.

DR. BELKNAP: If I could follow up on that a little bit. The problem that David addressed that sea level rise is continuing and this is just one more increment in that rise. I think we ought to be thinking about this project as part of the bigger picture. I think just putting more rows of concrete blocks on top of our existing seawalls is not the solution. We have to think about legislative and social solutions to a moving coastline. And this is one mechanism we can continue to think about that, like a moving set back law.

MR. AVTGES: I can assure you that if there are mitigation measures that require structural changes to any Corps project that we'd have to work with the states and the locals and we'd have to be consistent with the coastal zone law and so on. So the Corps will not go in there and just build and add to the walls.

DR. FINK: Just a comment on Dan's suggestion of the moving setback or some sort of a setback regulation. Such a proposal for the coast of Maine, not just in the face of increase in the high tide range but just in the face of continuing rise of sea level, accelerated perhaps by the greenhouse effect. This was considered some years ago by a fairly blue ribbon group of coastal geologist that met in Scarboro, and the upshot of that discussion following two days of what the beach dynamics of the coast of Maine were and what sort of legislative solution, long-term legislative solution might be, we really only came up with two.

One was some sort of a repurchase plan; that is, as soon as a house is damaged to the degree of 50 percent or more, something like that, there is a fund established by which the landowner can make a choice. He can either rebuild himself or take the money and go to a new location. And the second conclusion that was reached that any sort of a setback line has to be somewhere along the mainland, the upland; in other words, beyond the landward edge of the present marshes behind the barrier systems.

MR. SHIP: I'm Craig Ship from the University of Maine.

Something that came up in the tape and certainly in light of the most recent boundary dispute over the Gulf of Maine. I'd like to address this first to Dr. Greenberg and then to Dr. Larsen. The indication on the tape of the Canadian reaction and then Dr. Greenberg's comments about the competitive nature of American science, I would like to address and have both Dr. Larsen and Dr. Greenberg comment, is we've had a lot of facts here today on whether this reaction between Canadian and American is real, and if it is, what can be done about it?

DR. GREENBERG: I almost cringed in horror when I heard about that cross-border feeling which I don't think is there. I get the feeling that Peter's view toward the construction of a tidal power dam corresponds with some of the American views -- sorry, the Canadian views and maybe even most people here that they'll look at tidal power as they'll look at any other scheme and compare it to what's available and then think whether that's worthwhile or not.

As for Peter being an alarmist, I think no, that was what Peter's job was. Peter was trying to identify things that might happen and he wasn't coming up with conclusions saying that

they would happen, and that was what had to be identified, and in press and other reports it tends to come out as, my god, Maine is going to disappear. I think if anything, the Canadians reacted to maybe a little bit of over press reaction, and I think most of the reaction was, no scientists with any brains at all would have said that, and even Peter probably didn't. (Laughter)

DR. LARSEN: I think Dave got off to a good start on that answer. I'd just like to reiterate that I don't either believe that there is any this cross-border animosity. This report had the full cooperation of not only the Canadian scientific community but of George Baker and the Fundy Tidal Power Corporation. Without their help it would not have been possible to do. They saw it was in everybody's best interest. Obviously you cannot build, you can't even propose let alone build a project of this magnitude with major unanswered environmental questions.

There is a tendency -- I've learned a lot in this experience about politics and press as well as science. The press have this tenancy. The stores is always more exciting if you ever two sides to it. Except in very rare cases, I don't think there are any sides at all yet. We just don't know enough to take positions. Without saying any more, I think any of this cross-border stuff is creature of the media and not the people involved.

MR. AVTGES: Any other questions? Comments?

(No response.)

MR. AVTGES: We'll take a 15-minute break. Come back at 9:45.

(A recess was taken.)

MR. AVTGES: Just one point I'd like to clarify that on the funding, Senator Mitchell did get the language in the Senate Bill, but the Senate Bill is part of an overall water resources development act that has not been acted on by Congress, and it's highly unlikely that it would be acted on this year. So if Congress comes back, they may act on it, but again it's highly unlikely, and with the new Congress it has to be new legislation. So we're not too optimistic on any legislation authorizing work on the Bay of Fundy.

Now I'd like to turn over the mike to Dr. Suzette May who will handle the next session.

PANEL DISCUSSION - RISING SEA LEVEL

DR. MAY: Good morning. For the rest of morning we'll be discussing the issue of Sea Level Rise. Our panelists assisting in the discussion this morning are Dr. Daniel Belnap from the University of Maine; Ms. Barbara Braatz from Woods Hole Oceanographic Institute; and Dr. Joseph Kelley from the Maine Geological Survey.

I'd like to open this session by asking each of the participants to make a statement addressing the first two issues that are listed in the program, mainly, what are the problems? Can we identify the issues in terms of sea level? What types of problems are associated with the projected levels of sea level rise?

When we talk about sea level rise, we are really talking about relative water levels. There are a host of problems

that come into play when we begin to talk about sea level variations beyond just a global eustatic sea level change. We are also talking about associated problems brought on by subsidence, seasonal water level changes, and short-term as well long-term sea level changes.

I have found recently that there is often a misconception or miscommunication between the geological scientific community and the engineering community in these matters, which is generally a matter of perception of time scales. The time scale issue was also mentioned in the paper that we heard a little earlier this morning. The types of problems that we face when we are talking about time scales are illustrated when we see 5000 years of incremental millimeter scale changes become a major issue geologically, but difficult to adapt to planning design time scales of 50 to 100 years.

We should look at some of these questions and some of the projections that have been made recently, especially by the EPA. I think everyone is somewhat familiar with the EPA sea level rise scenarios which project a sea level rise of as much as 12 feet over the next century. That is a major issue to coastal communities, if one assumes that the EPA values are correct. There has been some discussion there which perhaps should be addressed this morning.

I would like to start this session with Dan Belnap. If you would please present your view of the major issues, major problems and concerns that we face both in the scientific sense and as you see it in terms of planning and engineering development.

DR. BELKNAP: I think Suzette hit it right on the head. When the issue of time scales is brought up, there often is a mismatch between geological perceptions and engineering perceptions. However, I think that the longer term understanding of how sea level rise affects coastal systems is an important factor to be considered in the shorter term issues, even in these issues of a one or two year rise of 15 centimeters.

As examples of time scale changes here are some sea level curves from Maine, the local relative sea level curves that have been worked out from various sources of information. We have in yellow probably the best guess at long-term sea level change in the coast of Maine and the Gulf of Maine modified from Schnitker in 1974. Joe Kelley talked about this yesterday. The glacial isostatic rebound, the low stand shoreline minus 65 meters, and the sea-level rise to its present position.

On the other hand, we have a time scale on the right from about 6000 years ago to present, and the scale of five meters. And even here there is a scale problem. We have scale in time and local scale differences between the south western coast and the Northeastern coast of Maine. The blue sea level curve is based on data from Timson '78 and Nelson and Fink '78, and seems to represent a slower rate of rise on the order of a millimeter per year or less over this long period of time. Whereas, in Addison, Maine on the northeastern coast, we have some information which seems to suggest an order of magnitude more rapid rise in that time period.

So before we can start asking for solutions to some of these problems, we have to identify the problems. We have to

identify which of these curves is valid, whether the data in the past has been collected properly, and whether the rates suggested by these kinds of information can be mapped on to our knowledge of coastal processes.

At the present Joe Kelley, Craig Ship and I are involved in several major projects along the coast of Maine addressing these issue. Here are some of the areas we've done some major work on. Question C here talks about the efforts we can make towards a solution of the problem. I'll defer that a bit just to say that we are working on this problem. We're actively involved in NSF, Nuclear Regulatory Commission and Sea Grant projects to address this question of how sea level rise affects erosion on the coast.

The issue as I see it is not simply one of beaches, not simply one of marshes or bluffs but how the whole coastal system as a natural geological system evolves and how that system interacts with human uses of the coast.

As an example of one of the geological systems, here is a marsh with some cores and some radiocarbon dates through it. We can see different scales of time of development of this marsh as sea level rises from a 3000 BP plane in red, a 2000 BP plane in orange and the 1000 BP plane in yellow. It's fairly obvious that there has been an acceleration of accumulation of the marsh sediments in the upper part of that curve.

What are the causes? Well, there are botanical effects as well geological effects. The interaction of the marsh plants with the sea level position is very important for the growth of this marsh. Also, the leading edge of this marsh as it has transgressed to the left in this slide and upward is determined by the sea level position and by the plants available.

How can we map this long-term scale on to a knowledge of changes of this marsh in the short term? Well, the pat answer is we need more studies. In this case it's true. We don't know much at all about the coast of Maine. We really have to do a great deal more study. We have to understand the botanical diversity, the effect of the geology in the coast of Maine and we're just getting started.

Many of the questions that have been raised today and at the rest of the conference can be answered, I believe, and will be answered. And I'd like to say that we can come up with at least suggestions that do not require large expenditures of money, such as major disruptive engineering projects. We can come up with rational solutions in terms of setbacks, mitigation and compensation, and I believe we ought to start planning for these things now. Thank you.

DR. MAY: Thank you, Dan.

Next I'd like to ask Ms. Barbara Braatz if she would address the issues. Again, the questions of what are the major issues in sea level research as she sees it, and what are the problems and some potential solutions to these problems?

MS. BRAATZ: First, I'd like to comment on a question I was asked yesterday. I was thinking about it last night and I don't think I gave -- well, I don't think my answer was perhaps adequate, I don't remember who asked me the question, but I think it went something like: Why are we using a sophisticated and perhaps confusing statistical technique to

analyze the tide gauge data when the values of the rate of sea level change that we come up with are so similar to previous studies? In other words, is eigenanalysis perhaps confusing the issue or clouding the data? I think that this is a very valid question.

I have run into this problem a number of times in previous studies that I've been involved with in a completely different field: paleo-oceanography. It is very "in" these days to do quantative studies. What has happened in paleo-oceanography is that people have applied methods such as eigenanalysis and principal component analysis to data sets because these methods provide very convenient methods of presenting the results. Sometimes these statistical techniques give no more information than the raw data, and so instead of providing further insight into a problem, the statistics only serve to confuse the issue for those people who do not understand the math behind the analysis.

However, I do not think that is the case for the sea level study. We are not looking at only individual station records. Instead we want to find the coherent modes of sea level change, the temporal and spatial structure in the data, which is something the regression and averaging techniques are not going to give us.

We want to know why sea level is changing. Spectral analysis of the temporal fluctuations give us the dominant frequencies in the signal. This can then be related to things that we know about, oceanographic fluctuations as well as climatic fluctuations.

Dave and I hope to take these analyses further by using another technique which is known as complex eigenanalysis or spectral eigenanalysis. The methods we're using at present only give us information about the stationary structure of the data. Complex eigenanalysis tells us about wave like features in the data. For instance, if there is some kind of atmospheric forcing in the Southern Hemisphere, perhaps that causes a wave like feature in sea level to move up a coastline. This is something that complex eigenanalysis would tell us.

So in response to the question (or how I interpreted it), I don't think that these statistical techniques are clouding the data. Regression and averaging techniques are certainly appropriate if we want to know what relative sea level is doing at individual stations. But in order to determine regional structure in sea level, eigenanalysis will give us a much more informative picture of the data.

Now, back to really what this panel discussion is about. As I said just before, we're interested in the regional structure of sea level. We want to find what is happening in particular areas around the globe. So what we need to do now is complete regional studies to properly define the regional tectonic, oceanographic and isostatic signals, and then we can use these studies to determine where new tide gauge stations are needed.

What we'd like to do is have a multidisciplinary group, including tectonophysicists, physical oceanographers, geologists, glaciologists, coastal engineers and climate modelers who will then provide us with a variety of information so we can set up long-term monitoring stations in sensitive areas, as well

as data points for climate modelers for model evaluation in critical areas.

We also need oceanographic studies to determine what the thermal expansion and freshening of the oceans has been in the last century or so. At present I only know of one study that's been done. Carl Wunsch and Dean Roemmich, in a reoccupation of two North Atlantic Oceanographic transects, looked at temperature rise and thermal expansion over the past 30 years. They found a temperature rise of about .3 to .4 degrees Centigrade, and an associated thermal expansion of a few centimeters.

We need to define a program of high quality observations of salinity and temperature along zonal ocean sections such as this study to monitor the long-term warming and expansion of global areas. These studies must coincide with previous hydrographic sections of high quality and must be extremely accurate.

We also need to understand vertical mixing processes in the deep water. What kind of dampening effect does the ocean have on atmospheric fluctuations in temperature and pressure. The study that Wunsch and Roemmich did showed that the temperature increase in the oceans occurred at mid-depths down to about 3000 meters. Previous climatic models, to my knowledge, have only included the temperature effects down to about a thousand meters.

And lastly, something that's of more interest to the people here, we need to unravel the United States East Coast signal. We can see that it's very complex. We have some ideas about what's going on, but we really need to find out more about isostatic readjustment, hydrostatic loading, tectonic structure and oceanographic fluctuations along this coastline to figure out how these factors affect relative movements of the land and the oceans.

DR. MAY: Thank you, Barbara.

Joe Kelley from the Maine Geological Survey, would you please address these issues.

DR. KELLEY: I will probably end up simply reiterating what has been said. I see three general issues regarding sea level rise. Specifically, what is the rate of sea level rise; that is, how local is it, how local does one have to go to determine sea level rise. In the State of Maine we have four tide gauges. They all yield a very different record. Maybe we need 25 tide gauges to determine how sea level is locally rising.

Basically this revolves around the question of isolation of the factors that lead to apparent relative sea level rise, rivering contributions that are known to significantly affect the apparent rate of sea level rise, meteorological factors, the temperature of the ocean certainly, the rate of melting of ice caps, storm events, high and low pressure systems and so forth, certainly affect apparent local rates of sea level rise, and finally tectonic factors. Even within the State of Maine, a relatively restricted region, we have found crustal warping to be a significant factor affecting local rates of sea level rise.

How to measure these rates of rise? I would just point out again an excellent summary or comparison of two techniques that one commonly sees used to evaluate rates of sea

level rise. Relevel of the first order level network and tide gauge measurement were compared by Mr. Larry Brown from Cornell, published in 1978 in the journal entitled Tectonophysics. He found these two techniques, each highly precise in its own way yielded order of magnitude differences in measurements. He came to no conclusion as to which was in error, but they were both purported to be very accurate, and yet they disagreed completely.

Dan has already talked about the long and short term rates of rise. I think it's important as a geologist to look back and evaluate rates, the long-term rate of sea level rise and the resultant sedimentological record derived from that rise to better understand what is going to happen today.

So rates of rise, another issue would be the effects of rise. And in a general sense I would suggest that sediment redistribution is the most important process resulting from sea level rise. Sediment redistribution is driven by changes in sea level over geological time, and certainly in a contemporary time schedule.

Specific mechanisms that are affected by sea level rise operate generally at or very near the shoreline itself. What is needed is a quantification of the rates of sediment redistribution. This illustration was used in a proposal and paper by Dan Belnap and myself wherein we talk about the redistribution of sediment; that is, the contribution of eroding bluffs to our estuaries; the variable rates of sediment accumulation on mudflats, the loss of some areas where sediment might accumulate; that is, the loss of environments like salt marshes and the formation of salt marshes in other regions.

As sea level rises this ideal estuary, of course, transgresses. Area one, the landward area there is what area three looked like sometime in the past. Then in accord with Walther's Law, these various zones will move in a landward direction. I think it's very important to put numbers on those various arrows and begin to establish at what rate sediment is introduced and moved through and possibly exported from our embayments and estuaries.

And the final issue related to sea level rise that I would see is more of a legal or socioeconomic one: How do we translate these numbers into meaningful terms to the public? How do we inform our elected representatives that there are changes taking place along our coastline that, although we have to talk about fairly long-term, long time periods to understand these changes or to really see them, they are nonetheless significant.

I flew into Boston the other day. I don't even know where this is. I was looking out the north side of the window, and I see one way to address the problem of sea level rise and sediment redistribution. We see a source of sediment, a bluff that presumably in times past fed sand into a nearshore beach system and mud into an adjacent salt marsh. It has been riprapped today to protect what appears to be a reservoir. We see a myriad of engineering structures, most of which do not appear to be succeeding in maintaining an environment to protect a handful of houses which have a certain and very measurable value but I wonder, what will this scene look like in a hundred years? I cannot conceive of it looking like this. I wonder how much more money will be required to maintain this sort of quasi-stability

that we see.

So I think we as scientist must convince our elected officials that things are taking place and that our convictions must be translated into some sort of land use or zoning along the coast so that certainly my home State of Maine doesn't come to look like our neighbor to the south, Massachusetts. Thank you.

DR. MAY: Thank you, Joe.

I think from the preceding three commentaries we can see that there are several issues that we all agree on that need to be addressed. The major one, of course, is the verification of the accuracy and the validity of the sea level estimates that we're using today. And with that issue goes hand in hand the issue of better data sets. How can we achieve this? What do we need? Do we need more tide gauges? Are tide gauges the best way to estimate sea level rise?

In view of these problems, and I think that Joe very nicely summarized some of the critical issues of disseminating the information to the appropriate officials, both planners and developers, and in making the public aware of what potential effects are, slow progressive inundation of our coastal areas, that I would like now to ask the panelists to address the issues of how they see that these objectives of information dissemination, cooperation, multiagencies of research and research cooperatives, how this can best be achieved. Do they have any constructive ideas for developing better data sets for our use, and if there are any constructive ideas towards disseminating this information to the public.

Joe, would you care to start?

DR. KELLEY: One is trained as a scientist for many years and then one gets asked the questions, something of this sort, how do you achieve these goals? I've never been trained to organize and address a problem of this sort really.

Clearly a multidisciplinary problems are the problems of the future. We've always acted as scientists within our own disciplines in the past. Clearly I think we need more multidisciplinary organizations. The model I mentioned before, the Estuarine Research Federation is one in which meetings on a bi-annual basis provide a mechanism for people of different discipline to come together.

As I mentioned previous, more significant than that, however, is bringing individuals even within the same discipline, such as geology together when they are in different organizations which frequently compete for the same sources of funds.

I think perhaps an issue like the potential rise and change of the tides with Fundy tidal power might actually represent an opportunity for different groups to come together under the aegis of the Army or whatever organization comes to fund research projects, if they ever come into existence might actually turn out to be a benefit to us; that is, bringing people from Canada, from the United States both from federal, state, private sector organizations to solving a common problem.

Communication, I suppose, among scientists is the principal way we solve problems, and communication within science is principally addressed by journals and by meetings. So I suppose I would say that perhaps a common journal addressing sea level rise or annual meetings related to the subject would be two

approaches probably most effectively bringing people together to talk about these problems.

MS. BRAATZ: What I have to say is essentially along the same lines as Joe. I think that this is certainly an interdisciplinary problem, and as I mentioned before, we hope to have an interdisciplinary group to determine where new tide gauge stations are to be located. I personally feel this is one of the best ways to get a handle on sea level. And I believe that Dave Aubrey is working with NOAA to set this up now.

I know that there were stations or there are stations I think in the Southern hemisphere, perhaps Central America, South America, that were previously monitored by our government, and we stopped monitoring them because we didn't feel this was an important problem. They are now going to be starting up again, and I think the increased awareness of this problem is going to help us in perhaps getting together more and better data and getting a better handle on what actually is going on with sea level.

DR. BELKNAP: I think the points about interdisciplinary research and conferences are well made. I'd like to make the concrete suggestion that we continue this type of meeting. I think annually might be too much for the Army, but perhaps bi-annually would be fine.

I think in the past there's been a lack of communication between the Corps of Engineers and coastal sedimentologists, in fact a confrontational situation which is not necessary, and I think there is no blame to be placed. I think we can both help each other. I think the Corps of Engineers is probably the proper group to be handling the oversight on this problem. And I would be perfectly comfortable working with you on that.

I think this kind of conference where we can discuss the kind of issues that have been raised is important. And I'd like to see it continue.

As to the future, I believe that we can't continue in this competitive vein. I think we have to go to the interdisciplinary approach. We need the large science approach on these very complex issues. In fact, there is a group being put together reported on in Science Magazine a few months back, complex problems in science, talking about weather, climatic change, circulation in the ocean and so on. We may not be at that scale of complexity, but we still have a complex problem which needs biologist, geologists, geodesists, geophysicists, engineers to come up to these reasonable solutions.

DR. MAY: Thank you, Dan.

Before turning the meeting back over to Nick and to open questions, I'd just like to ask the panelists if they have any other final comments they want to make, either in a technical vein or addressing any of the sociological or planning issues? Barbara?

MS. BRAATZ: I'd just wanted to make a brief comment on the NPR tape we heard earlier. There were a lot of laughs in the audience, and I certainly was laughing along with it. It seems as if a lot of the views that came forth on that tape were somewhat extremist. And unfortunately, I think that's one of the ways that the public will rally to a cause, so to speak. It's not

until the issue really gets to be a "hot" issue or alarming that people start to make a move towards solving a problem. And I think that it is something you have to accept. The press is a very important disseminator of information. And if somehow they realize that sea level rise is important, that there are a lot of problems associated with it and the impacts could be perhaps disastrous, they will get a-hold of issues such as this and make the public more aware of them.

DR. MAY: Any other comments?

(No response.)

DR. MAY: In that case we can turn it over to Nick and open it up to the general group.

MR. AVTGES: At this time I'd like to have Bill Donovan from our Washington office say a few words. Bill has been recently serving in the capacity of Assistant Chief of the Planning Division in our Washington office. Bill.

MR. DONOVAN: I'll just say a few things. I don't really have a lot to say, except that from the OCE perspective, I'd like to compliment the New England Division for putting on a really very excellent first-time conference here in the area of coastal planning and coastal engineering, and indicate it's taken a lot of initiative and a lot of effort to go into this area, and I think particularly Tom Bruha, the Chief of the Coastal Protection Section in NED has certainly done a heck of job on this.

And I happen in my particular job work very close with General Wall, Director of Civil Works, as you know, and I've been working with him lately on a lot of stuff relating to the Department of the Interior. It doesn't relate to this conference, but when I was meeting with him one day early last week, in the course of our discussion on coast of California, I mentioned I was coming up to this meeting. So he said, "I hope it's going to be a good meeting, Bill." And I'm scheduled to meet with him on this coming Tuesday when I'm back there. And given his nature, he'll say, "How was the meeting?" So I'll honestly be able to say to him that I think it was a very good meeting, a kind of productive meeting, and a very stimulating meeting. So I think plaudits to NED, and of course, everybody who participated in the meeting that's made it the successes that I perceive it to be.

One of the things I liked very much about this particular meeting is even though it's been a Corps sponsored and Corps directed conference put together, if you look at the agenda and all the people that participated, it was far from just the Corps speaking to itself, but rather the Corps participating with some very able people, but a great deal of able people from a variety of other institutes and state programs and so forth. I think that's made the thing very viable and very ranging. So it hasn't been the Corps trying to pocket its own views. Rather I think, maybe John Smith mentioned at the outset that the Corps has been here and has been a participant but yet we've all been able to listen and listen very, very carefully and learn a few things.

I don't think it was intended at the outset, as I understand from the planning for the particular meeting that we've been at, but it would almost seem that as an after thought as the way the meetings has gone, two topics and both closely related. In fact, there is one major kind of a topic which has been sort of

sea level rise has been in the background or in the forefront of almost all of the discussions and primarily relates in two ways: One, to this whole Bay of Fundy discussion that's been going on. It has significant implications for the whole Gulf of Maine and down south of that. And then the more broader but yet related and sort of confounds it is the increasing concern we've seen here in the last year with the discussions and the reports of the EPA and then another report somewhat moderate, not as general a meeting, that was put out by the National Academy, also on the sea level problem from the national or really the global perspective.

And as you ponder those particular studies in the global perspective and then the Bay of Fundy activitys and plans that's going on and the implications for that and the difficulties of getting ahold of the actual effects and a lot of work to be done on the Bay of Fundy implication, yet there can be confounded with if indeed some of those predictions are right or even only partially right and the national global perspective of sea level rise, you have sort of a sea level rise thrust and the implications of that certainly in this region for the two major concerns or activity or views that I mentioned.

So I've been glad to be able to come, and I'll be happy to report back to General Wall that I think the conference from the perspective of where I sit and where I report back to has been a very, very good one. I've listened and learned a lot. I've just made a few comments but mainly it's been very useful from my perspective.

I would make another comment on the Bay of Fundy. As you hear with all the tremendous regional focus and the Canadian people and the local state people and, of course, our New England people, you get a real sense that this is right up front. It's a major concern. It's a very sensitive thing, and I think locally and regionally it is. But if you were back in Washington caught up in the larger context of where a lot of programs in the U.S. government are going and so forth, you'd have to listen very, very carefully to be aware that the Bay of Fundy and the implications for all of the coast of the Gulf of Maine and southward is basically known. It is not.

I begin to see in various publication I look at little snippets of ideas and comments on this. So maybe it's starting to emerge. But we recently had this bill that naturally the Corps and its supporters were hoping would go through the Congress, an authorizing bill. It would have including, if you looked way back in it, some study funding that would relate to this problem up here. But of course the whole bill was washed out, and we're sill in the same position we were as we go into the new Congress as that may be made up coming in after January, and a whole new start in taking a look at the water problems and the water needs and appropriate authorizations, including any assistance and involvement we might have formally with regard to this Bay of Fundy type of implications and study on the United States side that's so significant.

So all of that is yet to come if it's going come, and there will be a whole new start in January, whatever that start may be, to get the support say for this study and other things too. So I think one could come out of here with the perspective that it's very much up front, and that it isn't the

local area. But I think there is an awful lot of work to be done at the national level, and I suppose that is the work of people from the State of Maine and from their elected representatives and in other ways to bring this more to the forefront, and I would see that it is from the position I happen to sit in.

But again, I'm very happy to have been invited to see this conference in action and to have been privileged to listen and learn, and again I want to compliment the Division, and I'd like to compliment all the attendees and participants for really an excellent set of presentations and some very provocative insights and questions, not all of them necessarily answered that have been raised throughout the course of this two days. Thank you, Nick.

MR. AVTGES: Thanks, Bill.

Does anyone have any final thoughts or comments they would like to make?

MR. ANDERSON: My name is Walter Anderson. I'm the Director and state geologist of the Maine Geological Survey.

The comments that the panel had made concerning this multidisciplinary, multiagency approach may at first blush seem rather a formidable one, but I'd like to point out that the State of Maine anyway in addressing the sea level rise issue that we're all concerned about has in a sense already gone a long way towards developing exactly that technique. It's such a big issue. It's such an important one, and also one that is going to require large sums of money to address, and it's one that I think most of the participatns, the scientists, and the policymakers in the state have realized that we must take this approach in order not to dilute the overall effort but to concentrate the best talents in this area.

And what has happened, when we began this program on crustal warping in the State of Maine back in 1978, I believe it was, we set out to contact and develop a program with a wide variety of disciplines, both in the technical, nonhistorical history, geophysicists, geodesists, archaeologistss, University of Maine types, academicians, state agencies. A wide variety of people have been involved in this thing.

And now I see with the meeting that we have here today, this critical mass is actually gaining even more momentum because I see here in this audience people who can further contribute, I think, to what Maine has already in some ways gone a long way towards accomplishing. There's a paper that's about to come out in geology, I think, in November which kind of summarizes the programs and the people and the specialties, disciplines that were involved in this thing. And I think by using that as sort of a model and developing the programs further with the kind of people I see around here today, I can see there is a very good potential and there is a very good feeling in the State of Maine about continuing on and expanding this sort of thing. That's all I have to say. Thank you:

MR. AVTGES: Curt?

MR. MASON: Curt Mason, Corps of Engineers.

Joe's comment about the addition of 25 tide gauges to the Maine tide gauging program got me thinking a little bit, and just a comment about the fact that in trying to measure this sea level rise rate, you are looking at very small numbers in

millimeters of water level change.

There are some very subtle things that can go on with tide gauges that some people are aware of and other people are not. And whoever is using this data should be very careful that the tide gauge information is accurate.

We were working with NOAA on improving techniques for measuring open ocean tides. We see a 10 percent error due to wave -- 10 percent of the incident wave height error in the mean water level due to incident wave height. We see set down in tide gauges records due to currents.

In the interior portions where many of the tide gauges are located in bays and estuaries, you can get very subtle shifts in mean water level over a long period of time just due to dredging of the channel entrance. If they put a deep draft channel in, you're going to mess up the hydraulics some that are going to cause some very small changes in the mean water level in the bay. If you're on a single piling in an unconsolidated sediment, the thing can go down.

Just a word of caution that there are many reasons for relative sea level rise that may have nothing to do with the fact that the water levels is coming up.

MR. AVTGES: Anybody else?

(No response.)

MR. AVTGES: At this time on behalf of New England Division of the Corps of Engineers, I'd like to thank all the speakers and participants. I'd like to commend John Smith, Chief of the Coastal Development Branch and his staff, especially Tom Bruha, for an outstanding job. A lot of time and effort went into this, and I know from my point of view it was worthwhile.

I'd like to remind everyone if you haven't filled out the questionnaire, either fill it out now or mail it to us. We will look at these questionnaires and determine the future of meetings of this type. This meeting resulted from a national meeting that was held, I guess some of you attended, down at the Cape last October, and following that meeting our Division Engineer recommended that we set it up on a regional basis to try and get our regional problems and discuss it in an open forum, and that was the purpose of this one.

So with that, if anyone else has any comments.

MR. BRUHA: I just want to say that it's nice to have your name at the top of the list, but when you go down into the trenches, there are many people that have to all cooperate and participate in making something like this what we hoped it would be, a success. And I'd like to start by thanking John Smith who is the Branch Chief and Jim Doucakis, Ms. Cathy LeBlanc, Dr. Frank Fessenden, Jennifer Dick, Barbara Carlson, Ann Wright, and Margret Roberts. I want to thank them for their cooperation in this, and I want to be sure that they get credit for doing a big part of supporting me and putting up with me for the last couple of months. Thank you all for coming.

(Whereupon, at 10:36 o'clock a.m., the conference was closed.)

APPENDIX

GUEST SPEAKERS AND PANELISTS

1ST REGIONAL COASTAL ENGINEERING CONFERENCE

Guest Speakers and Panelists

Name	Telephone Number
Ms. Barbara Braatz Woods Hole Oceanographic Institute Woods Hole, MA 20543	617-548-1400
Mr. Duncan Fitzgerald Boston University Geology Department 725 Commonwealth Avenue Boston, MA 02215	617-353-2530
Dr. Kenneth Fink University of Maine Ira C. Darling Center Walpole, ME 04573	207-563-3146
Mr. David Keeley Maine State Planning Office 184 State Street Station No. 38 Augusta, ME 04333	207-289-3261
Dr. Joseph Kelley Director of Marine Geology Maine Geological Survey State House Station 22 Augusta, ME 04333	207-289-2801 (Augusta) 207-581-2162 (Orono)
Mr. Neil Ross Marine Advisory Service University of Rhode Island Narragansett Bay Campus Narragansett, RI 02882	401-792-6211
Mr. Steven Onysko, P.E. Consulting Civil and Coastal Engineer 82 Hazelton Street Cranston, RI 02920	401-944-1949

Guest Speakers and Panelists (cont'd)

Name	Telephone Number
Dr. David Greenberg Bedford Institute of Oceanography P.O. Box 1006 Dartmouth, Nova Scotia B2Y4A2	902-426-2431 902-865-7511 (Home)
Dr. Pete Larsen Bigelow Laboratory West Booth Bay Harbor, ME 04575	207-633-2173
Dr. James Houston Chief, Research Division (WESCR) Coastal Engineering Research Center Waterways Experiment Station P.O. Box 631 Vicksburg, MS 39180-0631	8-542-2056 601-634-3492
Dr. Suzette May Coastal Engineering Research Center Research Division (WESCR-P) USAE Waterways Experiment Station Vicksburg, MS 39180-0631	8-542-2056 601-634-2056
Mr. Michael J. Trawle Hydraulic Laboratory (WESHE-R) USAE Waterways Experiment Station Vicksburg, MS 39180-0631	8-542-3518 601-634-3518
Mr. THomas W. Richardson Chief, Coastal Structures and Evaluation Branch (WESCD-S) Waterways Experiment Station P.O. Box 631 Vicksburg, MS 39180-0631	8-542-2019 601-634-2019
Dr. Edward Thompson Chief, Coastal Oceanographic Branch (WESCR-O) Waterways Experiment Station P.O. Box 631 Vicksburg, MS 39180-0631	8-542-2027 601-634-2027

Guest Speakers and Panelists (cont'd)

Name	Telephone Number
Mr. H. Lee Butler Chief, Coastal Processes Branch (WESCR-P) Research Division Coastal Engineering Research Center Waterways Experiment Station P.O. Box 631 Vicksburg, MS 39180-0631	8-542-2405 601-634-2405
Mr. Malcolm L. Spaulding Applied Science Associates, Inc. 529 Main Street Wakefield, RI 02879	401-789-6224
Dr. Larry L. Daggett Hydraulic Engineer Hydraulic Laboratory (WESHE-M) USAE Waterways Experiment Station Vicksburg, MS 39180-0631	8-542-2259
Mr. Lawrence Gatto U.S. Army Corps of Engineers Cold Region Research Engineering Laboratory P.O. Box 282 Hanover, New Hampshire 03755	8-836-4273 603-646-4273
Mr. Curt Mason Chief, Field Research Facility S.R. Box 271 Kitty Hawk, N.C. 27949	919-261-3511
Dr. Daniel Belknap Dept. of Geological Sciences Bordman Hall Orono, ME 04469	207-581-2159

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